Food and Agriculture Organization of the United Nations

European Bank for Reconstruction and Development

Morocco

Adoption of climate technologies in the agrifood sector

COUNTRY HIGHLIGHTS

FAO INVESTMENT CENTRE

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FOREWORD

The European Bank for Reconstruction and Development (EBRD) has been working in collaboration with the Food and Agriculture Organisation of the United Nations (FAO) towards a shared goal of enhancing resource efficiency and environmental sustainability in global agrifood systems. As a major source of greenhouse gas (GHG) emissions, these systems are under increasing pressure to reduce the environmental footprint of their activities. The promotion of green technologies within agrifood supply chains is an important strategy to advance this goal. This report represents one of many initiatives pursued over the last several years by the EBRD and FAO to reduce GHG emissions in the global agrifood sector and maximise associated benefits, such as enhanced resource and environmental sustainability.

The EBRD, in coordination with other regional development banks, is pursuing its commitment to climate change mitigation and adaptation through its participation in the Climate Technology Transfer Initiative Programme, funded by the Global Environment Facility (GEF). The programme works to increase the deployment and dissemination of climate mitigation and adaptation technologies.

Among other initiatives, the EBRD co-finances the project *Finance and Technology Transfer Centre for Climate Change* (FINTECC), which supports businesses in implementing green technologies, largely through grants for eligible technologies and technical support. It also aims to enhance technological uptake by helping policymakers and businesses overcome the risks and barriers associated with particular technologies and practices.

The promotion of climate technologies and practices also lies at the heart of FAO's work, which seeks to make food and agricultural systems more efficient while enhancing the productivity and sustainability of agriculture, forestry and fishery industries. Through its extensive experience in addressing these themes, FAO has developed numerous analytical tools to advance these objectives, which the FINTECC project builds on and complements.

Within this context, the EBRD and FAO started collaborating on the methodology document "Monitoring the adoption of key sustainable climate technologies in the agrifood sector". This study involved several FAO technical divisions and was also conducted in coordination with the International Energy Agency (IEA). The study is intended to provide guidance for tracking technology adoption rates in agrifood supply chains and also to inform policymakers and investors on opportunities to increase the uptake of climate technologies.

The present document applies the methodology to the case of Morocco and provides legislators and businesses with a better understanding of the market penetration of selected green technologies in Morocco's agrifood sector. It also highlights the potential for improvements in the use of climate-related technologies and practices and offers multiple perspectives to policymakers and investors (financial, economic, environmental, social and legislative, among others) on the utility of each technology and practice. Morocco has already launched an ambitious national programme to combat climate change and enhance environmental sustainability, and the findings of this report are expected to contribute to current and future climate action initiatives at the national level, while providing an example that can be replicated in other countries.

Key results indicate that in Morocco, the majority of emissions (slightly over 80 percent) from agriculture come from enteric fermentation and manure left on pastures. When taking into account financial, economic, environmental sustainability and social considerations, the analysis of 12 selected technologies and practices concludes that an increase in the uptake of conservation agriculture, efficient field machinery, renewable energy systems, and efficient cold storages would reap the largest rewards in terms of reducing agrifood GHG emissions and promoting resource efficiency and other related benefits.

The report also finds that for the technologies and practices considered, access to and the cost of capital, financial returns, and regulatory/institutional issues (such as regulations and technology specifications) represent the largest constraints to adopting climate technologies in Morocco. Finally the report also highlights interesting sustainability issues that need to be carefully considered in specific technologies, for example in the case of solar powered irrigation and consequent use of groundwater resources.

The conclusions of the Morocco report assume increased importance in light of the upcoming 22nd session of the Conference of the Parties (COP22) for the United Nations Framework Convention on Climate Change (UNFCCC), held in Marrakech in November 2016. The findings of the document will be discussed at the COP22 and could promote national and international climate change mitigation and adaptation efforts in two crucial ways. Specifically, the document could facilitate cross-country comparisons to increase technological uptake, while also providing cross-technologies comparisons within the same country. In this way, the Morocco pilot study, coupled with the methodology document, can contribute to enhanced regional and international cooperation on climate change action.

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ACRONYMS AND ABBREVIATIONS

ADA	Agricultural Development Agency
ADEREE	*Agence Nationale pour le Développement des Energies Renouvelables et de l'Efficacité Energétique* (National Agency for the Development of Renewable Energy and Energy Efficiency)
AFEX	Arab Future Energy Index
ALGEES	Alternative Green Energy and Environment Solutions
AMISOLE	*Association Marocaine des Industries Solaires et Eoliennes* (Moroccan Association of Solar and Wind Industries)
CA	conservation agriculture
CAM	*Crédit Agricole du Maroc*
CCA	climate change adaptation
CFC	chlorofluorocarbon
CGEM	*Confédération Générale des Entreprises du Maroc* (General Confederation of Companies of Morocco)
CMB	*Comité Marocain des Barrages* (Moroccan Committee for Dams)
COPERMA	*Conserverie les Perles de Marrakech*
DRPE	*Direction de la planification et de la recherche dans l'eau* (Direction of Planning and Research in Water)
EBRD	European Bank for Reconstruction and Development
EGFI	*Entreprise Générale de Fumisterie Industrielle* (General Industrial Company)
ESCWA	UN Economic and Social Commission for Western Asia
FDA	*Fonds de Développement Agricole* (Agricultural Development Fund)
FENAGRI	*Fédération Nationale de l'Agroalimentaire*
FENELEC	*Fédération Nationale de l'Electricité de l'Electronique et des Energies Renouvelables*
FIMALAIT	*Fédération Interprofessionnelle Marocaine du Lait* (Inter-professional Moroccan Federation of Milk)
FINTECC	Finance and Technology Transfer Centre for Climate Change
GEF	Global Environmental Facility
GHG	greenhouse gas
GLEAM-i	Global Livestock Environmental Assessment Model - interactive
GWP	global warming potential
HCFC	hydrochlorofluorocarbon
HCP	*Haut Commissariat au Plan* (High Commission for Planning)

HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
ICE-E	improving cold storage equipment
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IGT	innovative greenhouse technology
INDC	intended nationally determined contribution
INRA	*Institut National de la Recherche Agronomique* (French National Institute for Agronomic Research)
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRESEN	*Institut de Recherche en Energie Solaire et Energies Nouvelles* (Institute of Research on Solar Energy and New Energies)
LHV	lower heating value or calorific value
LPG	liquefied petroleum gas
LU	livestock units
MACC	marginal abatement cost curve
MAPM	*Ministère de l'Agriculture et de la Pêche Maritime* (Ministry of Agriculture and Maritime Fisheries)
MASEN	*Agence Marocaine de l'Énergie Solaire* (Moroccan Agency for Solar Energy)
MCA	multi-criteria analysis
MEM	*Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement* (Ministry of Energy, Mines, Water and the Environment)
METL	*Ministère de l'Equipement, du Transport et de la Logistique* (Ministry of Equipment, Transportation and Logistics)
MICEN	*Ministère de l'Industrie, du Commerce, de l'Investissement et de l'Economie Numérique* (Ministry of Industry, Trade and the Digital Economy)
NDC	national determined contribution
NENA	Near East and North Africa
NPV	net present value
NT	no-till technology
OECD	Organisation for Economic Co-operation and Development
O&M	operations and maintenance
ONCA	*Office National du Conseil Agricole* (National Office of Agricultural Council)
ONEE	*Office National de l'Electricité et de l'Eau Potable* (National Office of Electricity and Drinking Water)

ONSSA	*Office National de Sécurité Sanitaire des Produits Alimentaires* (National Office for the Health Safety of Food Products)
PANLCD	*Programme d'Action National de Lutte Contre la Désertification* (National Action Programme Against Desertification)
PICCPMV	*Projet d'Intégration du Changement Climatique dans la Mise en œuvre du Plan Maroc Vert* (Project of Integration of Climate Change in the *Plan Maroc Vert*)
PMV	*Plan Maroc Vert*
PNEEI	*Plan National d'Économie d'Eau d'Irrigation* (National Irrigation Water Savings Plan)
PPER	*Programme Pilote d'Électrification Rurale* (Rural Electrification Pilot Programme)
PPP	public-private partnership
PROMASOL	Development Programme of the Moroccan Market for Solar Water Heaters
PV	photovoltaic
RE	renewable energy
R&D	research and development
REUNET	Renewable Energy University Network
SDR	social discount rate
SIE	*Société d'Investissements Energétiques* (Energy Investments Society)
SNDD	*Stratégie Nationale de Développement Durable* (National Sustainable Development Strategy)
SNMA	*Stratégie Nationale de Mécanisation Agricole* (National Strategy for Agricultural Mechanisation)
SOGEFRIM	*Sté de Gestion des Entrepôts Frigorifiques de Marrakech* (Marrakech Cold Storage Management Company)
SWH	solar water heating
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
UNSD	United Nations Statistics Division
VFD	variable frequency drive
WACC	weighted average cost of capital
WEF	water-energy-food

EXECUTIVE SUMMARY

Agriculture, deforestation and other land use account for roughly 25 percent of all greenhouse gas (GHG) emissions (IPCC, 2014). When the share of industry related to agriculture is included, the agriculture sector is an even greater contributor to climate change. It is thus crucial to identify technologies and practices that ensure a high and sustainable level of agricultural production while reducing GHG emissions from the sector.

This report pilots a methodology developed to identify and assess a number of climate technologies that can contribute to the mitigation of GHG emissions in a country's agrifood sector. The analysis also suggests relevant policy areas that should be evaluated to incentivise the adoption of such technologies.

An overview of the methodology is provided below, followed by a brief explanation of how the present study can contribute to Morocco's already significant mitigation efforts and the data limitations faced. The results of the methodology as applied in Morocco are then summarised as follows: (i) key emitting activities in Morocco; (ii) selected technologies that have the potential to mitigate GHG emissions for such activities; (iii) mitigation costs and technical GHG mitigation potential of each technology; (iv) sustainability considerations; (v) barriers hindering further uptake; and (vi) enabling policies to foster technology adoption.

Methodology

The methodology used in this document was developed as part of a joint project between the Food and Agriculture Organization of the United Nations (FAO) and the European Bank for Reconstruction and Development (EBRD) in 2016. It benefited extensively from discussions with the International Energy Agency (IEA), which is involved in a similar approach with the EBRD on a broader range of economic sectors.

The methodology is a step-by-step approach to help identify which of the many agrifood climate technologies and practices should be prioritised based on mitigation potential under existing conditions and in light of several important criteria (the key ones being technical parameters, financial and economic feasibility and sustainability considerations). In addition, it seeks to identify barriers that may hinder technology adoption and suggests policy themes that may deserve greater attention to stimulate market penetration. The methodology is organized in four steps, with each intended to help the assessor answer specific questions:

- Step 1: Which are the most relevant agrifood related activities in terms of GHG emissions?
- Step 2: How can climate technologies/practices capable of mitigating the identified GHG emissions be prioritised based on market share and other techno-economic parameters?
- Step 3: What are the relevant issues in terms of sustainability and potential for adaptation to climate change that need to be considered when selecting/advocating for these technologies?
- Step 4: Which are the main barriers hindering uptake and how can they be addressed?

Four key issues should be taken into consideration when interpreting the results obtained through the application of this methodology.

First, the methodology has been designed as a rapid appraisal tool: a mixture of data sources is used according to the availability in the country, with variable coverage and quality across the subsectors and technologies being assessed. However, the approach can easily be adapted to a more in-depth exercise involving collection of primary data and more intense field work (depending on resources and time). The study mainly used official country and international data along with industry sources, information from civil society organizations and academia. It is therefore dependent on the quality of such sources and availability of data. The analysis was conducted by a team of international and local experts in close collaboration with country officials.

Second, the number of technologies taken into consideration and the simplified policy analysis presented here can be expanded. The evaluation methods and principles can be applied to more technologies as needed since they are general analytical tools. Indeed, future work should consider more technologies as this is a field that is constantly seeing advances. In addition, the policy analysis can be deepened in order to produce concrete reform proposals; in the rapid appraisal form taken in this document, the analysis seeks to simply identify key policy areas that can be explored further. Moving from policy themes to actual reform proposals is inherently a more transaction-intensive process involving multiple stakeholders under government leadership and can be a natural follow-up to the results of the present exercise.

Third, the methodology has been designed as a repeatable exercise. In principle, it can be applied recurrently in the future at appropriate time intervals assuming that most data sources have been identified. Repeating the implementation allows local authorities to monitor technology uptake, track how the adoption of specific technologies may be responding to policy reforms and add new technologies to the analysis as they become available internationally.

Finally, this step-by-step methodology seeks to reduce emissions from the agrifood sector while maximising co-benefits. Climate change adaptation (CCA) is therefore just one criterion impacting the classification of technologies – together with other sustainability considerations – based primarily on an assessment of technical, market and economic criteria. Such an approach may aid policymakers to screen technologies and attract international climate financing to mitigate emissions while maximising co-benefits. However, it is less suitable if the local priority is to adapt to climate change. For this reason, technologies such as small dams, biogas from agri-residues or grazing management, which may have an important value in making agriculture more resilient to climate change, rank relatively low compared to other technologies. A different analysis where adaptation co-benefits are preferentially weighted could nonetheless be performed.

A contribution to an already dynamic process in Morocco

Morocco is actively seeking to mitigate climate change and in many ways has led by example. It has committed early to inclusive green growth across economic sectors through improved management of natural resources and a focus on value addition (while taking into consideration delicate social issues). In many ways the country has therefore quickly moved ahead in committing to objectives before the endorsement of the United Nations' Sustainable Development Goals (SDGs) in September 2015 and this has set the stage as Morocco prepares to host the COP22 climate talks in November 2016.

As part of the key strategic documents produced to meet the country's commitments to mitigate and adapt to climate change, Morocco published its 3rd National Communication on GHGs to the United Nations Framework Convention on Climate Change (UNFCCC) and its Biennial Update Report in February 2016 with a comprehensive analysis on emissions and an extensive list of proposed initiatives, which include the agrifood sector.

The present document is thus expected to contribute to this important process and has been prepared in close consultation with the Strategy and Statistics Department of the Ministry of Agriculture and Maritime Fisheries (MAPM). Two small workshops presenting the preliminary results were held in Rabat in March and May 2016 and confirmed the interest of Government in this approach. In addition, the workshops highlighted the potential of the study to be used in support of ongoing Moroccan initiatives such as the preparation of its *Stratégie sobre en carbon*, which is being led by teams at the Climate Change, Biodiversity and Green Economy Department of the Ministry of Energy, Mines, Water and Environment, or the development of the national determined contribution (NDC) under the UNFCCC.

Another important feature of this analysis is that it is expected to directly contribute to and complement other studies and strategic documents addressing the importance of land use in Morocco. For example, FAO has produced four case studies on the application of its ex-ante carbon-balance tool (ex-ACT) in Morocco, which include an estimate of the carbon balance of the country's *Plan Maroc Vert* (PMV) Roadmap Strategy 2010–2030 (FAO, 2012d). Land use management plays an important role in climate mitigation and adaptation of agriculture as it can potentially emit or sequester large amounts of carbon dioxide from the atmosphere, depending on land use change trends and land management choices. For simplicity, land use and land use change-related emissions are not included in the GHG emission analysis of Step 1 and the present work therefore complements land use considerations from separate studies. The potential for carbon sequestration in the soil is, however, considered for the relevant technologies in the other steps of the methodology.

Data limitations

It should be stressed that a large part of the analysis is based on a mixture of FAOSTAT GHG emissions data estimated by FAO at Tier 1 of the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, data reported by different bodies in Morocco to international organizations as well as official national communication to the UNFCCC. Despite uncertainties surrounding GHG estimates, the data provide useful indications on trends and relative source strengths. Although not all GHG emission categories envisaged by the IPCC are reported in Morocco's national communication and the national GHG inventory, the additional data provided allowed a comparison with FAOSTAT data. In addition, emissions associated with energy consumption are highly uncertain and data reported by different agencies may differ significantly. Insofar as possible, the report has sought to highlight data differences, clarify the typology of data employed and highlight the specific assumptions or technical parameters used for producing final estimates.

The approach taken for emissions data was also used in the techno-economic assessment in Step 2 of the methodology, which covered 12 different technologies and practices. The data on market penetration used in this step have been extrapolated from a mixture of official data sources (whenever possible) combined with industry sources and experts' opinions. For example, this was the case for equipment such as boilers, solar-powered pumps or tractors and in part for livestock improved breed and diets and manure as soil amendment. Moreover, the financial returns on investments for a given technology have merged qualitative data from discussions with different stakeholders with simple models using specific case studies. Given the rapid appraisal nature of the exercise, such analysis cannot be considered as fully representative of the diversity of contexts in which technologies and practices can be applied in Morocco and is rather used as an indication of possible financial returns to different technologies. Similarly, regarding economic considerations, an effort was made to account for most subsidies, taxes and other possible distortions that create wedges between financial and economic prices. In many cases, simplifications had to made done because of data gaps.

Finally, it is important to note that the analysis results in an assessment using a one to three star rating throughout. This allows some degree of interpretation by analysts and can be subject to discussion. The intention of the report is to provide useful technical inputs to feed the debate on technology adoption in the agrifood sector, investment potential and associated policies. The results can be assessed in different ways and the information is provided for stakeholders to use for their own purposes.

Country results

Key emitting activities in Morocco

The analysis on key emitting activities performed for this study considers GHG shares and trends in the agrifood sector by source (e.g. enteric fermentation, synthetic fertilisers or crop residues) and by key commodities (e.g. meat, milk, cereals). The analysis shows that emission shares from various agricultural activities in Morocco are very much in line with the values for its neighbouring countries and are also approximately in line with the average values from a selection of Near East and North African (NENA) countries. Within agriculture, the main emitting activities in Morocco (similarly to countries located in the Maghreb region) are associated with enteric fermentation and manure left on pastures, which combined account for slightly more than 80 percent of total emissions from agriculture[1]. Including energy use in Morocco's agrifood sector (energy use accounts for under one-fourth of total emissions), enteric fermentation, manure management and manure left on pasture account for just below of 70 percent of total emissions. Energy in the agrifood sector accounts for under one-fourth of total emissions.

On the other hand, much lower or almost no emissions are associated with activities such as burning crop residues, cultivating organic soils and growing rice both in Morocco and its neighbouring countries.

On the basis of Step 1, and as depicted in Figure 1, the key emitting sources in the agrifood sector of the country are:

(i) Manure management: emissions have a much higher share than in the benchmark region and their trend has been on the rise. At the same time, GHG intensity of cattle meat production is high.

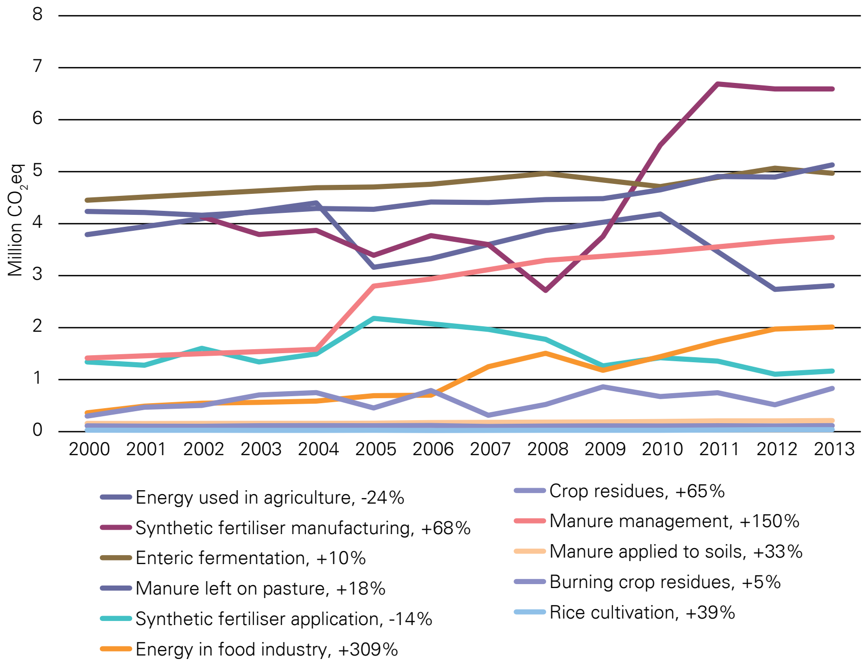
1 The GHGs emitted from enteric fermentation and manure are methane and nitrous oxide, which are much more powerful gases than nitrous oxide in their contribution to climate change. All the analysis here is done on a CO_2-equivalent (CO_2eq) basis.

(ii) Manure left on pasture: emissions share is lower than in the benchmark region; however, emissions are relevant in absolute terms and are on the rise. They contribute importantly to the high GHG intensity of cattle meat production.
(iii) Energy use in agriculture: the share of emissions is similar to the share of the benchmark region. The emissions trend has been increasing until recently, when there was a slight decrease.
(iv) Energy use in food processing: the share of emissions is smaller than in the benchmark region; however, the trend is on the rise.
(v) Enteric fermentation: emissions share from enteric fermentation is lower than in the benchmark region but is slightly increasing (+10 percent in 2013 compared to 2000). This is an important contributor to the high GHG intensity of cattle meat.
(vi) Synthetic fertiliser: the emissions share from synthetic fertiliser application (nitrous oxide due to application on the field) is similar to the benchmark region, although it has a decreasing trend. However, the amount of fertiliser use is increasing, resulting in more emissions associated with its manufacturing (carbon dioxide due to fossil fuel use).

These findings are overall in line with Morocco's recent intended national determined contribution (INDC)[2] to mitigate and adapt to climate change as indicated to the UNFCCC, where it is stated that the main sectors covered will be (i) enteric fermentation, (ii) manure management, (iii) cropping systems (together with land-use) and emissions from (iv) the energy sector, which includes agriculture and the agrifood industry.

2 For more information, please see Morocco INDC, 2015.

Figure 1: Trends of GHG emission sources from agriculture (including energy consumed on-farm and for fertiliser manufacturing) and food industry in Morocco, 2000–2013



Source: FAOSTAT (2015) and national GHG inventory for agriculture emissions, including energy use in agriculture; IEA (2015), HCP (2015) and authors' calculations for energy in food industry and fertiliser manufacturing.

Note: Although GHG emissions from burning and rice cultivation are negligible or non-existent in Morocco, they are reported here for consistency with the IPCC Guidelines (IPCC, 2006). The measurement is done at Tier 1. The term "agriculture" here refers to the subsectors "crops" and "livestock".

Technology choice

The emissions data analysis highlights the most critical agrifood activities in terms of GHG emissions (excluding land use), which in turn is the basis for identifying and selecting technologies and practices with potential to mitigate emissions from the sector. In addition, the decision on which technologies to assess was made based on best available technologies in the country and numerous discussions with local experts and, in particular, government officials.

The technologies and practices considered can be defined "climate technologies" since they are expected to reduce GHG emissions with a high level of confidence. Overall, 12 technologies were assessed in this process:

(i) conservation agriculture (CA) (defined here mostly as no-tillage), (ii) efficient field machinery, (iii) drip irrigation, (iv) solar/wind-powered water pumping, (v) grazing management, (vi) manure as soil amendment, (vii) livestock dairy breeds on improved diets, (viii) efficient water boilers, (ix) efficient cold storage, (x) biogas from manure and agri-residues (anaerobic digestion), (xi) RE systems and (xii) small dams.

Other technologies such as innovative greenhouse technologies (IGTs), solar dryers or cooking equipment were considered at an initial stage of the analysis, but were then excluded due to the lower relevance for the Moroccan agrifood sector. As indicated above, subsequent updates to this study by local or international stakeholders can easily add more technologies as required.

Mitigation costs and technical GHG mitigation potential

The techno-economic assessment conducted as part of Step 2 assessed all the technologies on the basis of seven criteria: (i) performance compared to international best practice, (ii) maturity of technical support services, (iii) potential to reduce GHG emissions, (iv) current market adoption rate, (v) trends in gap between current technology uptake and technical potential, (vi) financial attractiveness, and (vii) mitigation cost.

The results of the application of this methodology suggest that in the Moroccan context the technologies/practices that rank as having the highest techno-economic potential for large adoption and impact on GHG mitigation are: CA, efficient field machinery, and solar/wind water pumping, followed by efficient food cold storage, improved livestock breeding and diets, RE systems, drip irrigation, efficient water boilers, grazing management, and manure as soil amendment[3].

Small dams and biogas from agri-residues rank at the end of the list of the technologies/practices considered just from a techno-economic perspective. It should be stressed that some positive and negative impacts, including on climate adaptation or possible consequential effects, have not been considered up to this point of the assessment.

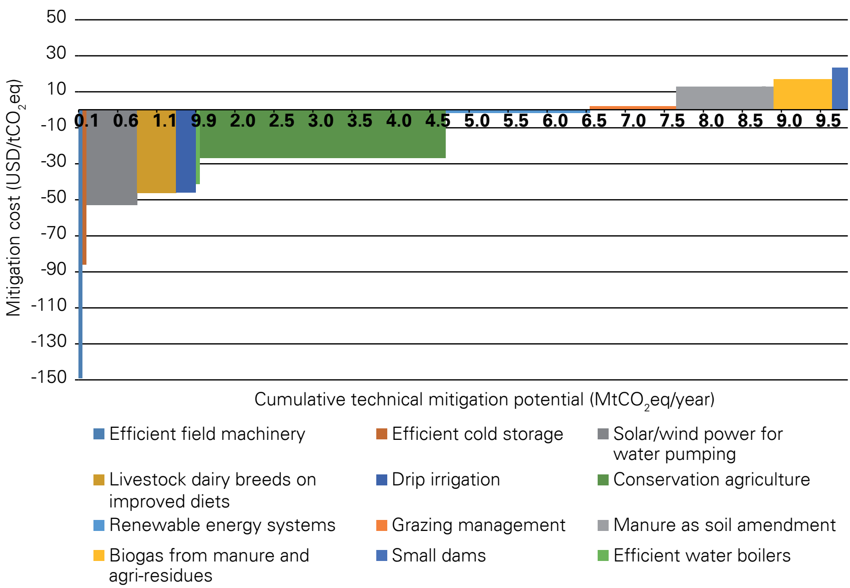
Based on the analysis in Step 2, it was possible to draw marginal abatement cost curves (MACCs) plotting (i) the estimated cost of mitigation by technology and (ii) the technical GHG mitigation potential. Figure 2 provides an indication of what mitigation would be technically achievable, with the area underlying the curve indicating the associated total cost. This analysis highlights that technologies and practices such as efficient water boilers, efficient field machinery and efficient cold storage could be implemented at very low (negative) mitigation costs but have a relatively low technical mitigation

3 See Table 4 for more information about the definition of technologies and practices in this study.

potential, while others such as CA or photovoltaic (PV) and wind energy would both have a negative cost while at the same time a high technical mitigation potential. On the other side, technologies and practices such as grazing management, manure as soil amendment and biogas would come at a cost, although with a high technical mitigation potential.

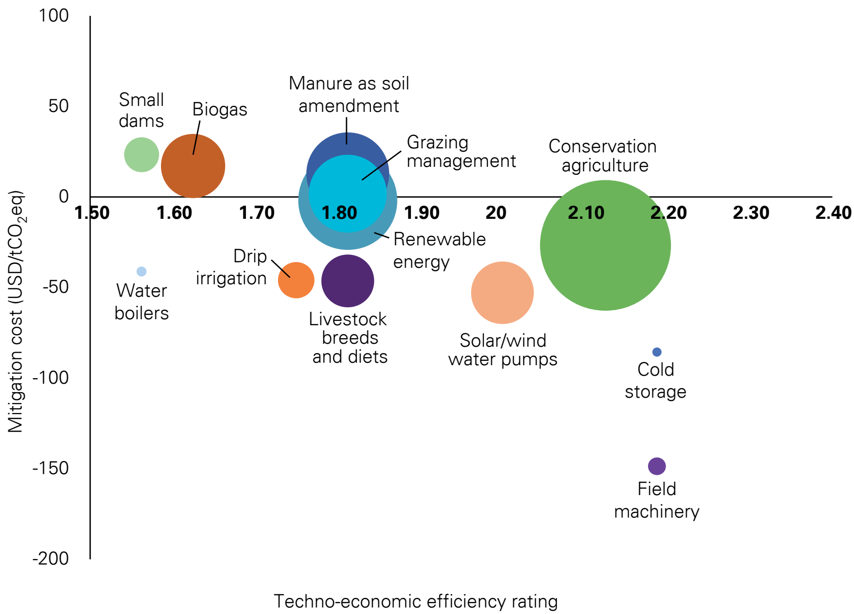
In addition to this analysis, Figure 3 provides an index measuring the performance of each technology based on all the criteria assessed under Step 2. In this second figure, the Y axis is the same (mitigation cost), while the X axis includes a quantitative aggregate final score based on the three star system for each technology and excluding the mitigation cost and technical GHG mitigation potential scores. The higher the aggregate score, the higher a technology is ranked. Moreover, the figure indicates the technical mitigation potential of each technology through the size of the bubbles. Figure 3 suggests a similar story to that of Figure 2.

Figure 2: Estimated cost of mitigation and technical GHG mitigation potential (cumulative) of agrifood technologies and practices in Morocco



Source: Authors' calculations.

Figure 3: Estimated cost of mitigation, other techno-economic criteria and technical GHG mitigation potential by technology/practice



Source: Authors' calculations.

Note: The size of the bubble indicates the technical mitigation potential.

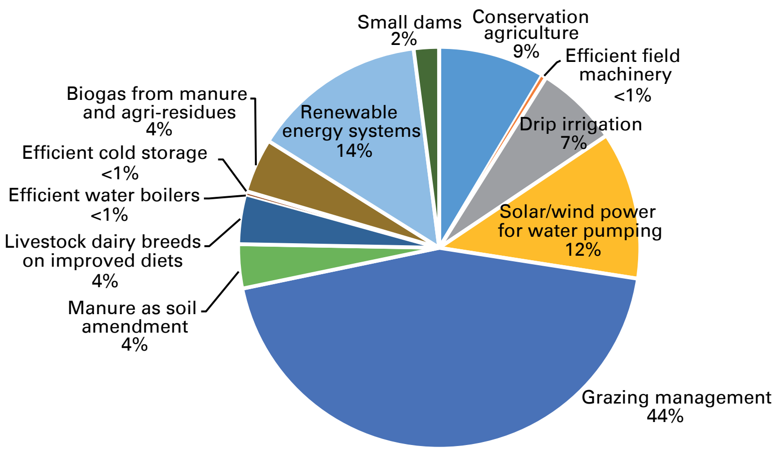
In order to correctly interpret the results from the index depicted in Figure 2, the assessor must consider that they result (i) from a three point classification for each criterion, (ii) from a weighted average between the criteria and (iii) from assessments often conducted with limited data points, particularly for the financial attractiveness indicator. Hence the results presented in the graph are indicative of the potential of each technology but deserve a closer look. In a nutshell:

- All technologies available in Morocco perform reasonably well when compared to international best practice and, despite the unavailability of well-trained technical support services countrywide, some technical support services already exist and can be replicated. An exception is made for biogas, though, for which there is little experience and limited technical knowledge in the country.
- CA, RE systems, manure as soil amendment and grazing management show the largest GHG mitigation potential.

- All technologies show considerable room for expanded adoption, but drip irrigation, improved livestock breeds and diets, and RE systems have seen considerable advances in adoption rates in the last decade, most likely due to a favourable policy framework. The remaining technologies may face stronger barriers to adoption that need to be addressed.
- Grazing management, manure as soil amendment, biogas and small dams have low financial returns, high initial capital costs and/or yield benefits only in the long run, thus they are currently less attractive to investors.
- Efficient field machinery, boilers and cold storage show considerably low (negative) mitigation costs, partly due to the fact that their mitigation potential (denominator) is low; solar and wind-powered pumps and improved livestock breeds and diets show both a low cost and a considerable mitigation potential.

Figure 4 summarises the share, for each technology, of the total investment required. This is defined as the cost of the capital and services needed to achieve each technology's GHG mitigation potential. It does not include incremental operational costs. Estimates are made based on the investment considered in each technology's financial model, scaled to address the entire estimated mitigation potential. As most models are not representative, they should be interpreted as indicative of the relative size of investment needed for each technology to achieve the total GHG mitigation potential.

Figure 4: Shares of estimated investment required to achieve total GHG emission reduction potential by technology/practice



Source: Authors' calculations.

Grazing management takes by far the largest share of total investment. This is due to an intervention in a large area (4.2 million ha) of the country and high unit investment costs (USD 1 470/ha), comprising fencing and plantations. GHG mitigation potential for grazing management is also amongst the highest for the analysed technologies, but the investment cost per tonne of CO_2eq mitigated is still the highest (estimates of carbon sequestration due to improved rangelands were conservative, however). The second largest investment requirements are from RE systems and solar and wind-powered water pumps. The former, having a high GHG mitigation potential, results in a median investment cost per tonne of CO_2eq. The latter, having a low GHG mitigation potential, results in a higher investment cost per tonne of CO_2eq. The same can be said for CA and drip irrigation, as the former has a much higher GHG mitigation potential than the latter. The remaining technologies require lower investments and have an investment cost to GHG mitigation potential ratio that is around or below the median.

Sustainability considerations

In Step 3, the analysis focuses on sustainability: technology solutions that score well in terms of technical and economic parameters often are not easily deployed due to environmental sustainability and social constraints, or other shadow costs to be borne by society[4]. Step 3 assesses the selected technologies and practices on the possible positive or negative implications they could have on: (i) the water sector (including water quality, use and availability), (ii) the energy sector (including fossil fuel dependency), (iii) the food sector (including land issues and food security), (iv) social implications and (v) contribution to CCA.

The analysis suggests that certain technologies and practices such as CA, manure as soil amendment, RE systems, small dams and the "energy efficient technologies" perform particularly well in most dimensions: they have either high relevance for CCA with minor concerns in terms of sustainability, or low relevance for CCA with no concerns in terms of sustainability. However, other technologies such as drip irrigation, solar or wind-powered pumping, grazing management and biogas may raise sustainability concerns as they are adopted. In particular, drip irrigation has positive land and food security implications but can lead to higher energy consumption trends in certain contexts due to the intensification of agriculture or to changing hydrological conditions in the watershed with consequences to water users downstream. Solar and wind-powered water pumps result in lower fossil fuel consumption and improved land, food security and social conditions, but may encourage increased groundwater exploitation. Moreover, introduction of improved grazing management practices can have positive implications but the technology would also require higher energy use (for land restoration and infrastructure).

4 The financial and economic sustainability is addressed chiefly in Step 2.

A preliminary analysis indicated that the most critical technology which might have negative sustainability impacts nationally is biogas. Despite positive energy implications, biogas may have a negative impact on water (increased water needs, risk of water pollution), land and food security implications (competition with other uses of residues), and social implications (need for more skilled labour) – though the latter constraint may encourage skills development within the local workforce.

Therefore, a more in-depth analysis for this technology was undertaken applying the FAO Nexus Rapid Appraisal, which considers the increase (or decrease) of resource use efficiency of the technology within the country context. In this specific case, the analysis did not highlight important trade-offs from a water-energy-food (WEF) nexus perspective, unless significant amounts of freshwater were needed to dilute the biogas feedstock.

Barriers hindering uptake

The analysis of the policy environment, in addition to the results of Steps 2 and 3, provides interesting insights into key types of barriers to adoption for the evaluated technologies. The results summarised in Step 4 of this document indicate that across all 12 technologies, access to and cost of capital, financial returns and regulatory/institutional issues (regulations, technology specifications) are important constraints to further adoption of climate technologies in Morocco. Organization and social issues (including social norms and behavior, collective action issues), as well as support services and structures (local research, coverage and efficiency of maintenance companies, etc.) are less important factors hindering adoption.

Moreover, the analysis suggests that there can be significant differences across technologies. For example, in the case of CA, knowledge about the technology and how to use it efficiently combined with a lack of support services seem like important factors hindering adoption. In the case of efficient field machinery, access to and cost of capital also play an important role; while for efficient cold storage, financial returns and access to capital are seen as the most important barriers combined with regulatory issues. This result is not surprising and suggests that a case-by-case approach is required in determining what kind of policy mix can support further technology uptake.

Enabling policies to foster technology adoption

In addition to highlighting the major obstacles to technology adoption (based mainly on Steps 2 and 3), Step 4 looks at historic market penetration and key policy changes before concluding which major thematic policy areas that could be addressed. It is difficult to find causality between a single policy and adoption of a technology, since the market development is normally the effect of a number of factors that often lie outside the policy realm or the national context (e.g. falling international prices of PV modules can have a direct effect on the adoption of PV pumps).

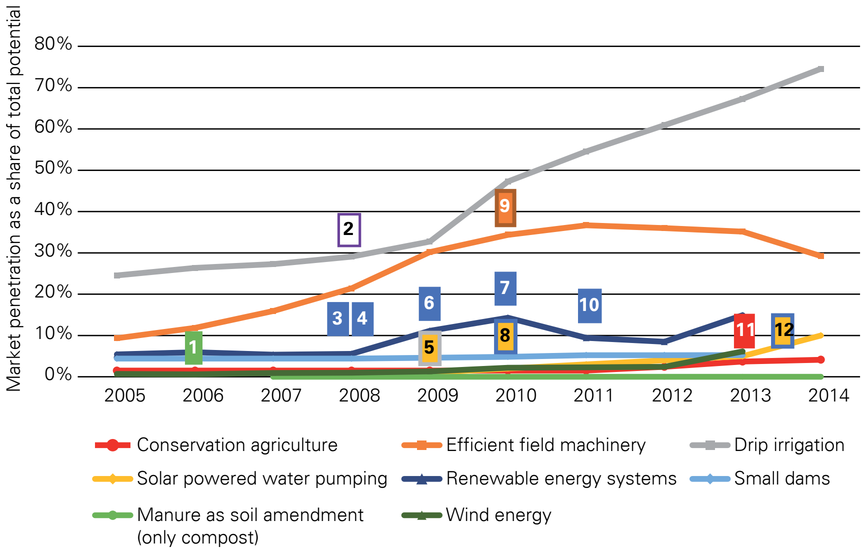
For example, in the case of CA it is too early to find causation between the introduction of a subsidy to purchase direct seeding equipment and the area under CA. It seems that a positive correlation exists, but this may be due to other factors such as the implementation of specific development projects (such as the PMV).

In contrast, the analysis also shows the possible lack of correlation between a policy intervention and the adoption of a technology. An evolution of the adoption of each technology is plotted in Figure 5 for the period 2005–2014 together with an indication of relevant policies that came into force each year.

The graph shows that the generation of electricity from RE sources (only wind electricity generation and hydropower are represented) has been increasing significantly in Morocco since 2008 (despite a drop in hydropower generation in 2011 and 2012, which was not indicative of a drop in production capacity), which is the year when the national energy strategy and the law on self-generation were implemented. Wind energy development in particular further increased after the implementation of the Renewable Energy Development law in 2009. The RE systems trend line does not represent PV energy due to data unavailability, but this may have followed a similar development to that of wind power. Likewise, solar water pumping has increased significantly since 2009 after the introduction of the National Water Strategy until 2030. Market penetration seems to have been further supported by the 2010 introduction of the National Integrated Project for Solar Electricity Production, the National Agency for Solar Energy and the Moroccan Agency for Solar Energy (MASEN) and the establishment of the *Agence Nationale pour le Développement des Énergies Renouvelables et l'Efficacité Énergétique* (National Agency for the Development of Renewable Energy and Energy Efficiency, ADEREE), as well as the elimination of subsidies on gasoline, fuel oil and fuel used for electricity generation in 2013.

The market penetration of drip irrigation shows a significant increase after the inception of the PMV. The PMV includes a number of policies which had and are having an impact on the whole agricultural sector in Morocco, far beyond the individual technologies analysed here – and not all policies are reported independently for simplicity. Looking at the PMV as a single package originally introduced in 2008, it appears that there may be a positive correlation between the PMV and the market penetration of solar water pumping and the introduction of new, more efficient tractors to support the development of the agricultural sector set by the PMV. No evident correlation can be found between the introduction of the PMV and CA, or with the production and use of compost. In the same way, it seems that the 2006 law on the management of agricultural waste disposal and treatment had no clear impact on composting practices in the country.

Figure 5: Historic market penetration, 2005-2014



Source: Authors' calculations.

Note: (i) For drip irrigation the numerator is the total number of hectares under drip irrigation reported by the MAF (e.g. 410 000 ha for 2014) whereas the denominator is the target set by the PNEEI/PMV of 550 000 hectares – hence the near achievement of the adoption potential. Considering the total potential of the 1 million ha under surface irrigation, the adoption rate would be reduced by nearly one-half; (ii) For efficient tractors, the adoption rate is estimated as the share of tractors less than 5 years old; (iii) RE adoption reported in terms of the share of electricity produced each year from hydropower and wind (iv) The remaining technologies use the market size and adoption as clearly indicated in Step 2.

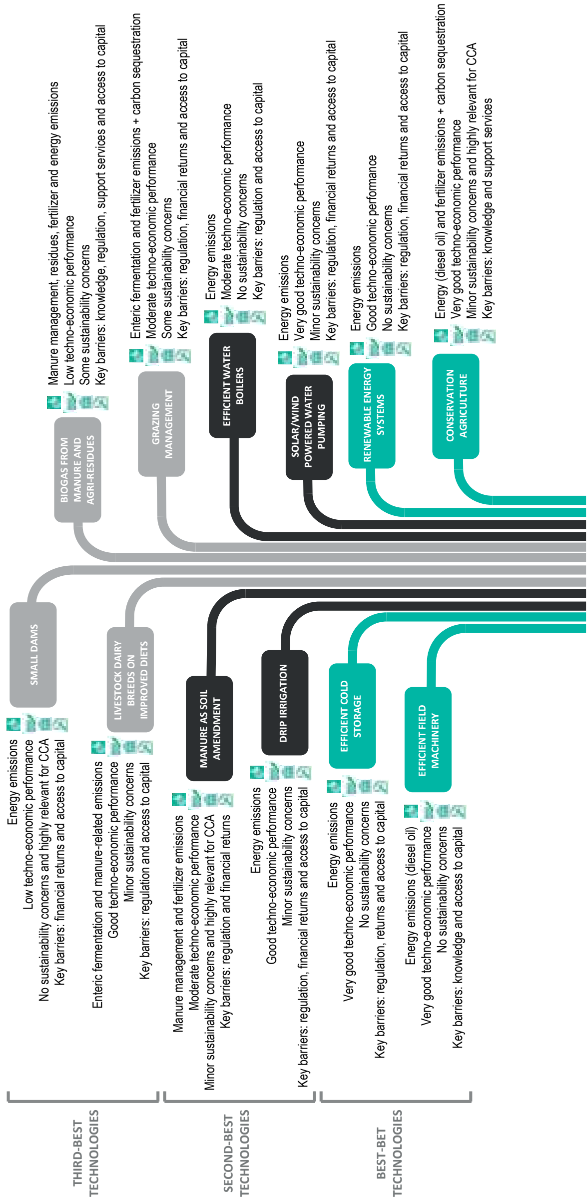
On the basis of the analysis of Steps 1 to 4, it is possible to identify the key sustainable climate technologies and practices that constitute "low-hanging fruit" for an institutional investor or a decision maker in the area of sustainable development (e.g. the government, a multilateral development organization or a donor). In other words, the climate technologies that can mitigate GHG-emitting activities (identified in Step 1) and that have good techno-economic performances (on the basis of Step 2), good environmental and social performances (on the basis of Step 3) and do not face barriers to adoption that are too difficult or time-consuming to address, are the "best-bet" technologies. The remaining technologies were classified as second- and third-best technologies as depicted in Figure 5 and further explained below. Again, this classification was established through a three point system with assigned weights for each indicator. The indicators were mainly focusing on potential market development and included economic, market and technical criteria. The classification also considered the assessment of environmental and socio-economic concerns/co-benefits under

Step 3. Results could change, even significantly, should the ranges or the weight attributed to the criteria be different.

The results from the application of the four step methodology to the Moroccan context show that CA, efficient field machinery, RE systems and efficient cold storage can be considered "low-hanging fruit" solutions to reduce GHG emissions from the agrifood sector while maximising co-benefits and minimising negative impacts on other sectors.

The identified policy interventions that could further spur the market penetration of these technologies would imply a medium to low intensity of reform. They could therefore be prioritised when choosing among a number of possible options. These technologies/practices are followed by solar and wind-powered water pumping, drip irrigation, efficient water boilers and manure as soil amendment. However, within this second group, solar/wind pumps and manure management are deemed to require a higher intensity of policy reform in order to be able to safely attract investments and increase their market penetration. Finally, grazing management, livestock dairy breeds on improved diets, biogas and small dams would require more targeted support in Morocco's current context, since their market development potential appears to be constrained for different reasons. This does not mean they should not be supported in the country but, on the contrary, they would require a more holistic support framework in order to overcome the barriers that hinder their full deployment (be they technical, economic, social, or regulatory), and/or to put in place all the social or environmental safeguards needed to avoid undesired negative effects.

Figure 6: Summary of results of the four step assessment



Source: Authors' compilation.

Introduction

Climate change plays an increasingly important role in the international debate on food security: how can we meet the food needs of 9.5 billion people under climate uncertainty? As a major contributor to greenhouse gases (GHGs), the agrifood sector is also coming under scrutiny to intensify its efforts to mitigate climate change. This is not surprising since worldwide, the agrifood chain (including agriculture, food processing, distribution, retail and utilisation) contributes to over 20 percent of total GHG emissions (excluding land use emissions) (FAO, 2011). Land use adds another 10 percent of global GHG emissions to this number (FAOSTAT, 2015).

Sustainable climate technology transfer has been widely recognised as a key component in the global strategy to reduce GHG emissions and address the challenges of climate change. While many climate technologies seem to hold much promise in terms of reducing emissions and contributing to climate change adaptation (CCA), numerous factors can hinder uptake in a specific country setting. Such factors include awareness of the technology, technical capacity and support services to use and maintain equipment, financial returns to investment, etc. In addition, a country's policy environment ranging from regulatory issues to direct price incentives can impact the risk-return equation for private investors and result in greater or lower adoption rates.

The European Bank for Reconstruction and Development (EBRD) and other regional development banks recognise the importance of technology in climate change, which is why they participate in the Climate Technology Transfer Initiative programme funded by the Global Environment Facility (GEF). The aim of this programme is to accelerate the dissemination and deployment of both climate mitigation and climate adaptation and resilience technologies. In particular, the EBRD is leading a set of activities aimed at supporting the market penetration of climate technologies in selected regions and co-financing the Finance and Technology Transfer Centre for Climate Change (FINTECC). FINTECC provides a framework established to demonstrate the viability of climate technologies. and includes a programme to help businesses implement innovative climate technologies, primarily through technical assistance and incentive grants for eligible technologies. The outcomes of the FINTECC Technical Cooperation Programme are intended to help legislators and investors in the private sector to overcome market barriers to the transfer of climate technologies and accelerate their deployment.

In the context of FINTECC, the Food and Agriculture Organization of the United Nations (FAO) and the EBRD have collaborated to develop a methodological tool that helps individual countries assess the degree of market penetration of climate technologies in their agrifood sectors. This entails monitoring progress of technology uptake, identifying good investment opportunities and spotting thematic policy areas that may warrant greater attention with respect to improving the investment climate for specific technologies. The work on the methodology was also done in close cooperation with the International Energy Agency (IEA), with which the EBRD has partnered on a parallel exercised that focused on the market penetration of energy efficiency and RE technologies in a broad range of industry sectors beyond just agrifood.

Following the first stage of methodological development (from the end of 2015 to the first half of 2016) and given the interest of the Moroccan Government, it was decided in close collaboration with the Ministry of Agriculture and Maritime Fisheries (MAPM) to hold the first pilot of the methodology in Morocco. The field work was conducted from November 2015 to February 2016 with multiple interactions with local experts, private sector, academia and public officials. It is expected that the pilot testing will provide insights into how to improve the methodology.

The methodology used throughout the document outlines a step-by-step approach to help identify which of the many agrifood climate technologies and practices should be prioritised based on the largest mitigation potential given existing conditions and in light of several criteria (technical, economic, sustainability, etc.). In addition, the methodology seeks to identify barriers that may be hindering technology adoption and suggest policy themes that may deserve greater attention in view of stimulating market penetration.

This report is organized in four parts based on the four steps of the methodology, with a final concluding section. The first section focuses on Step 1, which analyses emissions trends, shares and intensity, and seeks to identify the most relevant agrifood activities in terms of GHG emissions in Morocco. The second section (Step 2) provides the detailed techno-economic analyses of the different technologies and the final rankings based on the quantitative and qualitative analysis. The third section (Step 3) focuses on sustainability questions that may arise when upscaling the adoption of a specific technology in Morocco and also any climate adaptation benefits that were not considered in previous steps. The fourth section (Step 4) provides an overview of the policy framework in Morocco and analyses which key barriers may hinder technology uptake for each single technology assessed. Finally, the conclusion highlights the "low-hanging fruit" for policymakers and investors. Each section also has a small conclusion that provides a quick overview of key messages and ranks the technologies based on the criteria used.

More details on the methodology can be found in "Monitoring the adoption of sustainable climate technologies in the agrifood sector – Methodology document"[5]. The guidance document is an integral part of this study and it includes details about the possible data input and sources needed for the assessment, as well as a description of the criteria used and the underlying indicators. The indicators are both qualitative and quantitative and allow for measurement based on expert opinion.

5 **Sims, R., Flammini, A., Santos, N., Dias Pereira, L. & Bracco, S.** 2016 (forthcoming). *Monitoring the Adoption of Key Sustainable Climate Technologies in the Agrifood Sector – Methodology document. Draft, September.*

Step 1: Identifying the most relevant GHG-emitting agrifood activities

Step 1 provides an overview of the most relevant GHG emitting activities in the agrifood sector, building on reliable data already collected at the national level. The first source of information is FAOSTAT and, in particular, the GHG Emissions domain[6]. This domain uses activity data (e.g. hectares cultivated, dairy cattle population, fertiliser consumption in a given country, tonnes of diesel consumed in agriculture, plus many others) that national statistical offices report to FAO. It then applies the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines for GHGs to estimate the national emissions at Tier 1. It also provides information about the energy consumed in the agricultural sector[7] and expresses it in terms of GHG emissions.

More specifically, Step 1 is built around three sets of analysis focusing on: (i) current GHG emissions released by various agricultural activities in Morocco and their relative contribution to total agricultural GHG emissions, including energy used on-farm and in food processing; (ii) recent trends in agrifood GHG emissions; and (iii) GHG emission intensity (i.e. total emissions per unit of product) of key commodities produced in Morocco compared to those same commodities produced in benchmark countries.

For simplicity, land use and land use change emissions, including forestry[8], are not considered in Step 1. However, carbon sequestration is considered when relevant to assess the overall GHG mitigation potential and the mitigation cost of technologies in Step 2.

Due to the lack of a comprehensive and official dataset for assessing GHG emissions from the Moroccan agrifood sector, this analysis is based on a mixture of data sources reported by different bodies in Morocco to international organizations as well as on the official national communications to the UNFCCC. Therefore, the results of the analysis are approximate and should be treated as such.

6 FAOSTAT GHG Emissions - Agriculture domain: http://faostat3.fao.org/download/G1/*/E.

7 Agricultural emissions refer to primary production, i.e. emissions due to crop and livestock production and management activities. They exclude energy-related emissions due to fossil fuel burning.

8 Land use emissions consist of all the emissions and removals produced in the different land use sub-domains. GHG emissions and removals from forestry and other land use sectors consist of CO_2 and non-CO_2 gases (methane [CH_4] and nitrous oxide [N_2O]), produced by aerobic and anaerobic processes, e.g. combustion and decay, and by harvesting associated with land management activities. For more information please see http://faostat3.fao.org/mes/methodology_list/E.

GHG emission shares

Based on data provided by FAOSTAT, it is possible to calculate current agricultural emissions in a country, group of countries or region. In this case, we chose countries located in the Maghreb region[9] as benchmarks for Morocco due to proximity and similarity in geographical and climate conditions. The analysis occasionally also draws comparisons with countries around the Mediterranean with higher per capita income levels. This section starts by assessing GHG emissions from agriculture, which do not include emissions from the food industry nor emissions from energy used in agriculture based on FAOSTAT. It follows with emissions from energy use in agriculture and in the food industry and concludes with total emissions estimates. In addition, different sources of data are compared.

GHG emissions from agriculture

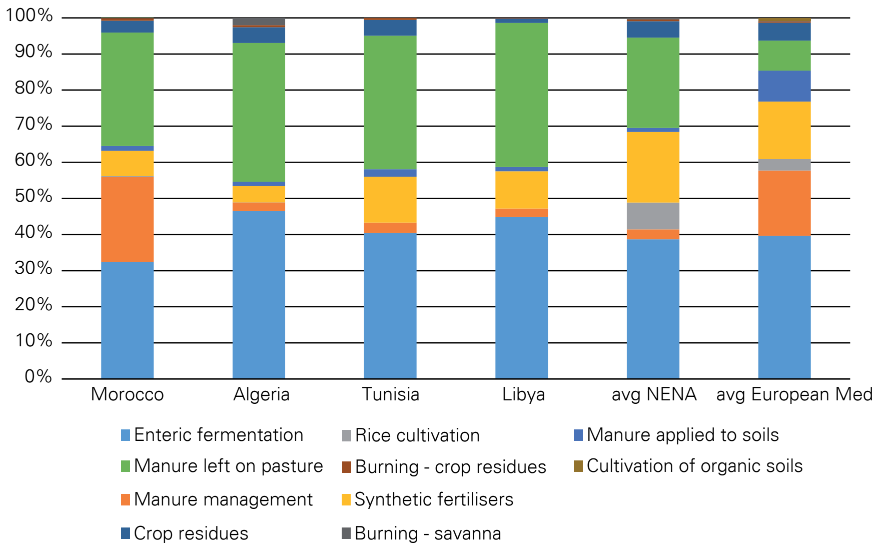
Figure 7 shows the estimated breakdown of GHG emissions data from the agricultural sector by activity. This analysis, based on FAOSTAT (2015) data for 2012, shows that emissions shares from most agricultural activities in Morocco are very much in line with the values for other Maghreb countries and also approximately in line with the average for a selection of Near East and North African (NENA) countries[10]. More specifically, the main emitting activities in countries located in the Maghreb region (excluding Morocco) are associated with enteric fermentation and manure left on pastures, which combined account for slightly more than 80 percent of total emissions from agriculture. On the other hand, much lower or almost no emissions are attributed to activities such as burning crop residues and cultivating organic soil and rice both in Morocco and in its neighbouring countries. Moving away from the Maghreb region (see Figure 7 for the averages of a selection of NENA and European Mediterranean countries), the weight of synthetic fertilisers and manure management in total emissions from agriculture increases beyond those of manure left on pasture. According to FAOSTAT data, while manure left on pasture accounts for almost 40 percent of total emissions from agriculture in Morocco (in line with its neighbouring countries in the Maghreb), it only accounts for 8 percent of emissions in higher per capita gross domestic product (GDP) countries in the Mediterranean (based on the average for France, Greece, Italy and Portugal). In addition, in European Mediterranean countries, manure applied to soils accounts for a significant share of total emissions (around 9 percent) while it is negligible in most other regions of the Mediterranean. Enteric fermentation remains the leading emitting activity in all of the countries (even those with higher per capita GDP and more developed agricultural sectors): the average share of agricultural

9 For the purpose of comparison. in this study we assume the following countries are part of the Maghreb region: Morocco, Algeria, Tunisia and Libya (Mauritania is excluded since the agricultural sector is significantly different from the others).

10 In this study, NENA includes Algeria, Tunisia, Lebanon, Libya, Egypt and Israel.

emissions from enteric fermentation in the European Mediterranean countries is 40 percent whereas it is only 33 percent in Morocco. Several factors including the typology of crops grown, agro-climatic conditions and farming techniques influence these outcomes. For example, emissions from synthetic fertilisers are much lower in Morocco and in Maghreb countries than in Egypt (27 percent of total emissions), Turkey (22 percent) or the average of the European Mediterranean countries (16 percent).

Figure 7: GHG emissions from agricultural activities in Morocco, selection of NENA and European Mediterranean countries, 2012



Source: Authors' calculations based on FAOSTAT, 2015.

Note: "Avg NENA" includes the average for Algeria, Tunisia, Lebanon, Libya, Egypt and Israel; "avg European Med" includes the average for France, Greece, Italy, Portugal and Spain. Emissions related to burning and rice cultivation are not relevant for Morocco but may be relevant for other countries/regions.

Table 1: Percent difference in Morocco's share of GHG emissions per activity relative to regional averages, 2012

GHG-emitting activity	avg Maghreb	avg NENA	avg European Med
Enteric fermentation	-4%[11]	+10%	+8%
Manure management	+5%	-4%	-578%
Rice cultivation	+99%	-1 644%	-640%
Synthetic fertilisers	+14%	-126%	-84%
Manure applied to soils	+13%	+32%	-423%
Manure left on pasture	+1%	+35%	+78%
Crop residues	+5%	-11%	-21%

Source: FAOSTAT, 2015.

Note: "Avg NENA" includes the average for Algeria, Tunisia, Lebanon, Egypt and Israel; "avg European Med" includes the average for France, Greece, Italy, Portugal and Spain; "avg Maghreb" is the average for Algeria, Tunisia and Libya.

Table 1 reports the percent difference between the emission shares of Morocco and those of other regions. Burning savannah, burning crop residues and organic soil cultivation have been excluded from the table and the analysis since the reported emissions associated with them are non-existent or negligible in the country. The analysis confirms that livestock-related emissions of Morocco are in line with those of the benchmark region. However, despite similar climatic conditions and agricultural products, Morocco emits a higher share of rice cultivation emissions than the other countries of the Maghreb region (+99 percent) and a moderately higher share of emissions from the application of synthetic fertilisers (+14 percent) and manure left on pasture (+13 percent).

Adding GHG emissions from energy used in agriculture and in the food industry to the picture

The analysis above can be complemented with information on GHG emissions from: (i) energy used in agriculture and (ii) energy used in the food industry.

Energy consumption in the agricultural sector (including the fisheries and forestry sectors but excluding the food industry) represents, in general, a small share of total final energy consumption, of around 2–4 percent in EU countries. This share is, however, significant in Morocco, reaching around 7 percent nowadays according to the Ministry of Energy, Mines, Water and the Environment (MEM). The key energy consumption items in the Moroccan

11 For example this means the enteric fermentation share of Morocco's GHG emissions in agriculture is 4 percent lower than the Maghreb region.

agricultural sector are irrigation systems, tractors, engines, dryers and livestock buildings (IFC, 2014).

Diesel oil is normally the main energy provider in the agricultural sector, being used in particular to fuel tractors, fishing boats and pumps (using both diesel and liquefied petroleum gas [LPG] as fuel). According to MEM data, in Morocco diesel oil consumption contributed to around 76 percent of the total agricultural energy consumption in 2012, but its share went down more recently, while the share of electricity and other cleaner fuels increased (up to around 25 percent in 2014).

It should be noted that emissions associated with energy consumption are highly uncertain and data reported by different agencies may differ significantly. Table 2 reports the data differences found for Morocco from the United Nations Statistics Division (UNSD), the IEA and MEM, both for energy consumed on farm and for food processing (the food industry). The table also shows that official statistics for the food industry are very scattered. In the present study, priority is given to official data as reported by the MEM and the *Haut-Commissariat au Plan* (HCP) when possible.

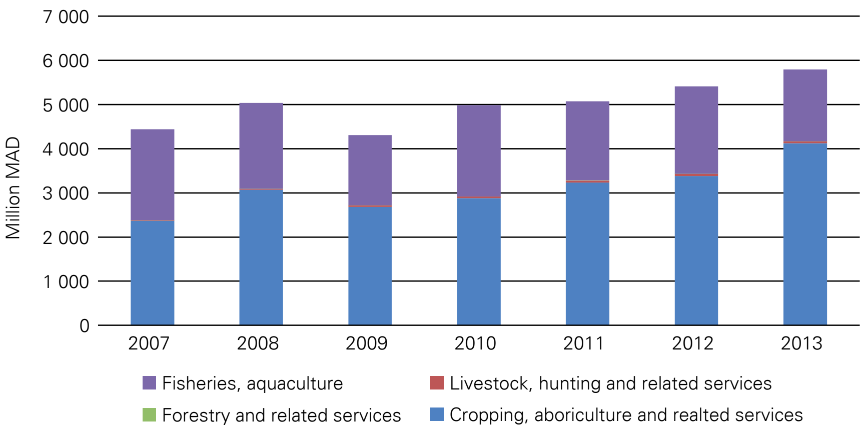
Table 2: Energy consumption data in Morocco for main energy carriers used in agriculture and associated GHG emissions, 2012

	Energy in agriculture			Energy in the food industry		
	UNSD	IEA	MEM	UNSD	IEA	MEM
Gas-diesel oil (PJ)	66.2	32.5	26.6	N/A	0	0
Motor gasoline (PJ)	N/A	0.4	0.5	N/A	0	0
LPG (PJ)	22.7	36.7	3.7	N/A	N/A	0
Coal (PJ)	0	0	0	0	1.0	0.33
Electricity (PJ)	5.8	5.0	10.6	N/A	4.0	0
GHG emissions (Mt CO_2eq)	8.1	6.0	4.3	N/A	0.8	0.03

Source: UNSD Energy Statistics Database, 2015; IEA Energy Statistics, 2014; MEM, 2016.

The different sets of activity data displayed in Table 2 have been checked against the data obtained from the national accounts as provided by the Moroccan HCP. For instance, UNSD statistics for agricultural energy consumption in Morocco seem significantly overestimated for the diesel component, at about 66 PJ. Our estimate based on the national accounts suggests approximately 25.5 PJ of diesel was consumed by the sector in 2012 – much closer to the 32.5 PJ value of the IEA statistics than the 66.2 PJ value of the UNSD statistics[12]. HCP data also shows that 28 percent of diesel used overall in agriculture in 2013 was actually for fisheries, the remainder being mostly used for crops and arboriculture (e.g. for irrigation purposes or to power field machinery) (Figure 8).

Figure 8: Diesel used in agriculture, 2007–2013



Source: HCP, 2015.

The official 2012 figure provided by the MEM and the associated official figure of GHG emission as reported in the national GHG inventory were used for reporting energy consumption by the agricultural sector in this study (the latest GHG inventory reports 2.7 metric tonnes (Mt) CO_2eq due to energy consumption of agriculture in 2012). On the other side, the MEM figures about energy used in the food industry (food processing) seem significantly underestimated, therefore Morocco's national accounts (Figure 9) and data provided by IEA were used to produce estimates of energy consumption in the food industry.

From the national accounts, the amount of diesel and fuel oil (the main fossil fuels used in food processing) was estimated at 5.4 PJ of diesel and 9.9 PJ of fuel oil, corresponding to 404 kilotonnes (kt) CO_2eq and 769 ktCO_2eq, respectively, in 2013[13]. For electricity used in food processing, the IEA value of

12 According to UNSD, the reason for the large difference is due to the fact that the last official submission of Morocco to UNSD on energy consumption was received in 2010, and since then UNSD projected the recent trend. However, according to official data, energy consumption in agriculture went down since 2010.

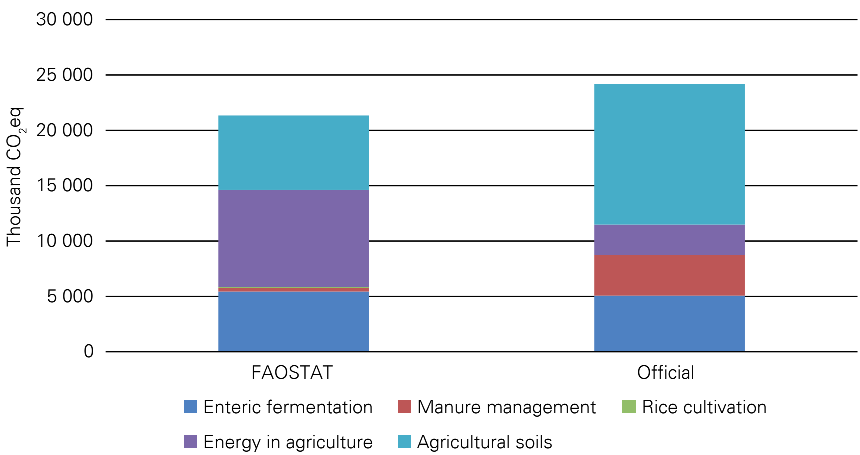
13 We assumed a cost of USD 1.11 per litre of diesel, and USD 466 per tonne of fuel oil (2013).

4.0 PJ in 2012 was adopted, corresponding to 765 ktCO_2eq emitted. In this way, we estimated a conservative total of 19.3 PJ consumed in food processing, or 1 938 ktCO_2eq emitted.

Complementing FAOSTAT data with official emission data and results

In February 2016, the 3rd National Communication on GHG of Morocco to the UNFCCC (MDCE, 2016) was published. Although not all GHG emission categories envisaged by the IPCC are reported in the national communication and the national GHG inventory, the additional data allows a comparison with FAOSTAT data. The comparison between these data sources is depicted in the two figures below: Figure 9 shows agricultural GHG emissions and energy use in agriculture while Figure 10 provides a comparison and a breakdown of emissions associated with cultivation of agricultural soils from FAOSTAT. The analysis shows that official GHG emission data for 2012 are: (i) similar to the ones provided by FAOSTAT for enteric fermentation; (ii) higher than FAOSTAT for manure management, as well as for agricultural soil-related emissions; and (iii) lower than FAOSTAT data for energy use in agriculture (2.7 MtCO_2eq instead of 8.1 MtCO_2eq). The resulting total emissions are similar and within the range of 21.3–24.2 Mt CO_2eq (Figure 9).

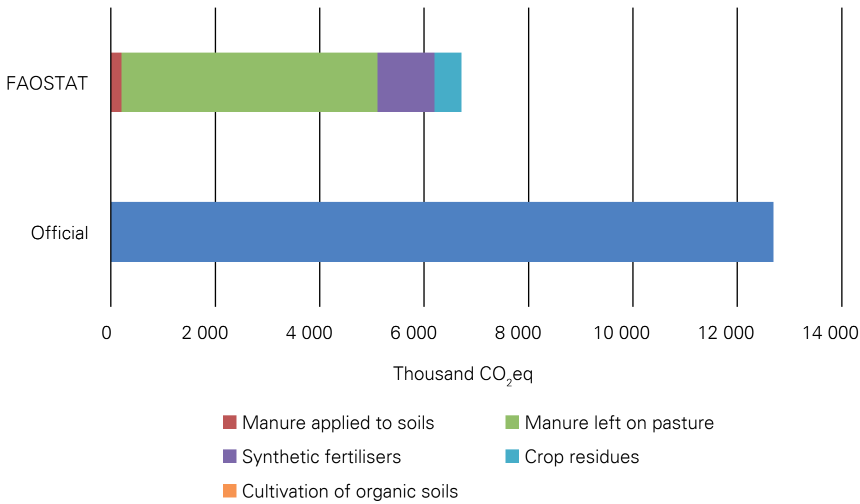
Figure 9: GHG emissions from agricultural activities and energy use in agriculture in Morocco reported by FAOSTAT and the 3rd National Communication, 2012



Source: FAOSTAT, 2015; 2012 National GHG inventory.

Note: Estimated following IPCC 2006 guidelines at Tier 1 and the 3rd national communication of Morocco to the UNFCCC released in February 2016 (estimated following IPCC, 1996).

Figure 10: Breakdown of GHG emissions from agricultural soils in Morocco reported by FAOSTAT and by the 2012 national GHG inventory, 2012



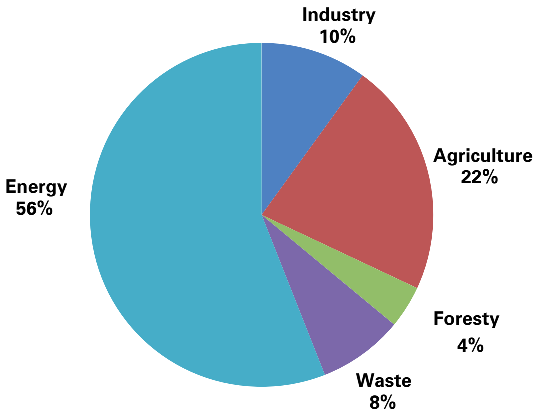
Source: FAOSTAT, 2015; 2012 National GHG inventory.

On the basis of the official figures for agricultural emissions and our estimate of emissions associated with energy consumed in food processing, 23.4 Mt CO_2eq was used as the estimate for total emissions from the agrifood sector in Morocco[14]. This is an important share of emissions when compared with a total of 100.5 MtCO_2eq for the whole country (MDCE, 2016). According to the 2012 national GHG inventory, agriculture alone (without food processing, including land use change and excluding energy) is in fact the second highest emitting sector in Morocco and responsible for 21.3 percent of total emissions (Figure 11)[15].

14 This figure excludes land use emissions.

15 According to the 3rd national communication, land use change was responsible for 9.5 Mt of CO_2 emissions and 4.4 Mt of CO_2 sequestration in 2012.

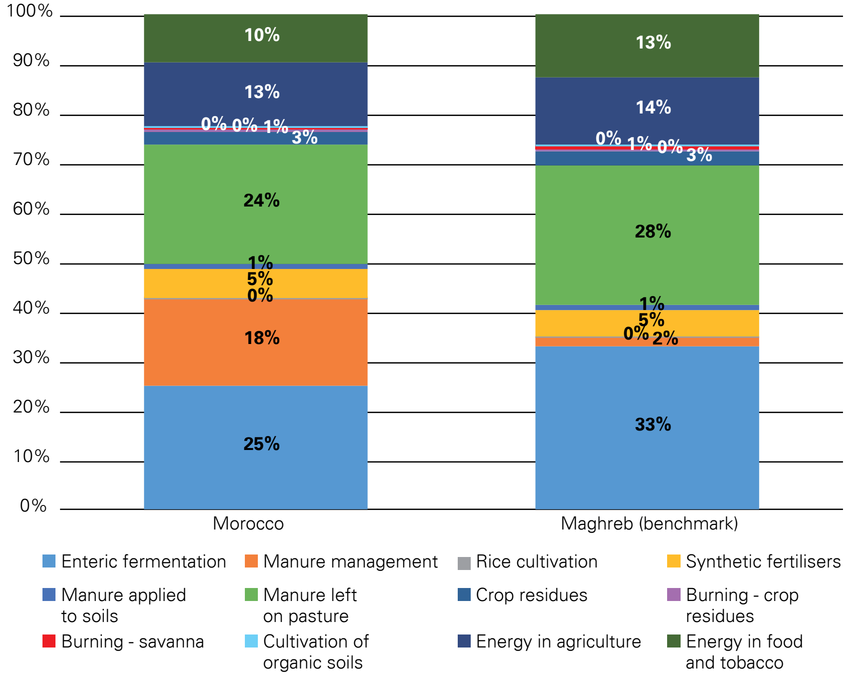
Figure 11: Breakdown of total emissions for Morocco (in CO_2eq) by IPCC module, 2012



Source: MDCE, 2016.

The resulting emissions of the agrifood sector, including energy used both on-farm and by the food industry for 2012–2013, are shown in Figure 12 for Morocco and the Maghreb region. These are based on the following sources: (i) UNSD statistics for energy used in agriculture, except Morocco for which MEM data were used; (ii) IEA data for energy used in the food industry for all countries except Morocco, where they were were complemented by HCP statistics; (iii) data from the national GHG inventory for agricultural emissions (including emissions from energy used in agriculture) (although FAOSTAT data were maintained for agricultural soils in Morocco, since they allow a breakdown of emissions by agricultural activity, which is not obtainable from the national GHG inventory). As explained previously, in percentage terms, the emissions from crop residues, manure applied to soils, manure left on pastures and synthetic fertilisers obtained are expected to be slightly larger in reality than what is presented in Figure 12 (according to the 3rd National Communication).

Figure 12: GHG emission shares of the agricultural and food industry sectors (including energy consumption) in Morocco and Maghreb, 2012–2013



Source: FAOSTAT; National Communication data; authors' calculations.

Note: Although GHG emissions from burning, rice cultivation and cultivation of organic soils are negligible or non-existent in Morocco, they are reported here for consistency with the IPCC Guidelines (IPCC, 2006).

This analysis confirms that livestock-related sources, namely those from enteric fermentation, manure left on pasture and manure management, and energy consumed in agriculture and in food processing are major emitters both in Morocco and in the benchmark region. Emissions associated with manure management are much more relevant in Morocco than in the Maghreb region, accounting for 18 percent in the former compared with just 2 percent in the latter. Emissions associated with fertiliser application, rice cultivation and manure applied to soils are also more relevant in Morocco than in the Maghreb, while emissions associated with crop residues and burning are less important in relative terms. Overall, the numbers are small in absolute terms.

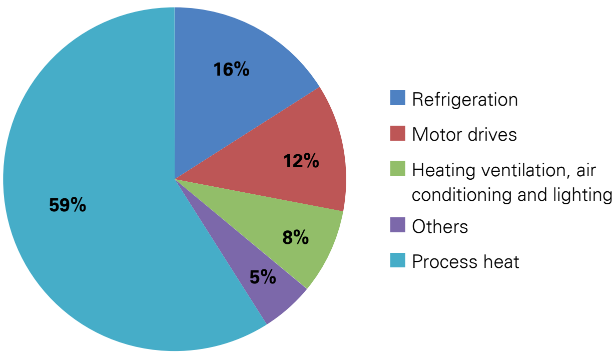
Breakdown of energy consumption in the agrifood sector

A closer analysis is needed to ascertain the actual sources of emissions due to energy consumption on-farm. Energy consumption on-farm comprises several agrifood activities and is therefore relevant to different technologies and practices that could be introduced, such as conservation agriculture (CA), efficient field machinery, drip irrigation, solar/wind-powered water pumping, innovative greenhouses, renewable energy (RE) systems, etc.

According to FAOSTAT, emissions from powering irrigation in Morocco were around 722 ktCO_2eq in 2012, accounting for approximately 30 percent of the total agrifood emissions. In fact, in 2010, energy demand for irrigation was estimated to be around 900 GWh and forecasted to remain stable over the following decade (El Badraoui & Berdai, 2011). About 650 GWh of this energy demand were related to areas irrigated with pumped groundwater, whereas about 230 GWh were related to surface irrigation systems (IFC, 2014). These figures are approximately consistent with FAOSTAT data of around 1 000 GWh (3 594 TJ) in 2012 for power irrigation in Morocco. Irrigation systems are therefore important energy consumers in Morocco, together with field machinery such as tractors (most of the energy consumed in agriculture is diesel fuel). Heat production on-farm is marginal in Morocco as well as the use of heated greenhouses.

The data collected did not allow a precise breakdown of energy consumption for the food industry. However, in order to obtain an estimate of the main final energy uses in food processing, the split provided by FAO/USAID (2015) was adopted (Figure 13). On the basis of discussions held with local experts in Morocco, these shares were largely confirmed, even if we can expect a slightly higher share for energy consumption from refrigeration and a smaller share for process heat.

Figure 13: Typical energy consumption by end users in the food processing industry



Source: FAO/USAID, 2015.

GHG emission trends

A second part of the analysis consists of looking at recent trends in order to highlight which activities have been significantly increasing or reducing their emissions recently[16]. For Morocco, this analysis is mostly based on FAOSTAT data but official emissions data for enteric fermentation, manure management, rice cultivation and energy used in agriculture replace FAOSTAT data in the analysis. Moreover, data on energy consumed in the food industry from 2007–2013 are based on HCP figures, while before 2007 they are based on IEA consumption data[17].

Figure 14 shows that from 2000–2013, emissions from manure management increased sharply, followed by emissions from crop residues. The latter are however much smaller in absolute terms.

Emissions from energy use in agriculture remained roughly stable until 2010, after which they decreased. This may be due to statistical reporting issues. Agriculture and forestry currently use 3 369 GWh annually, which is 11.8 percent of the country's total energy consumption, and have doubled their energy consumption from 1 538 GWh in 2011 (IEA, 2015).

Emissions from energy used in the food industry increased significantly over that time period but the trend is uncertain mainly because, as explained before, different references were used before and after 2007. However, given the overall trend, it can be stated with a good degree of certainty that GHG emissions from the food industry have been on the rise in recent years. Emissions from manure applied to soils and rice cultivation have also been on the rise, although to a lower extent.

It is interesting to note the trend of emissions associated with synthetic fertilisers: according to FAOSTAT estimates, N_2O emissions due to their application[18] decreased in Morocco; however, if we also add energy-related emissions due to synthetic fertiliser manufacturing[19] to the analysis, they show a significant increase (which did not necessarily take place in the country, but are linked to agricultural activity in the country regardless). These emissions correspond to around 6.6 $MtCO_2eq$ in 2013, according to our estimate, which makes synthetic fertiliser manufacturing the largest emitting activity among those considered.

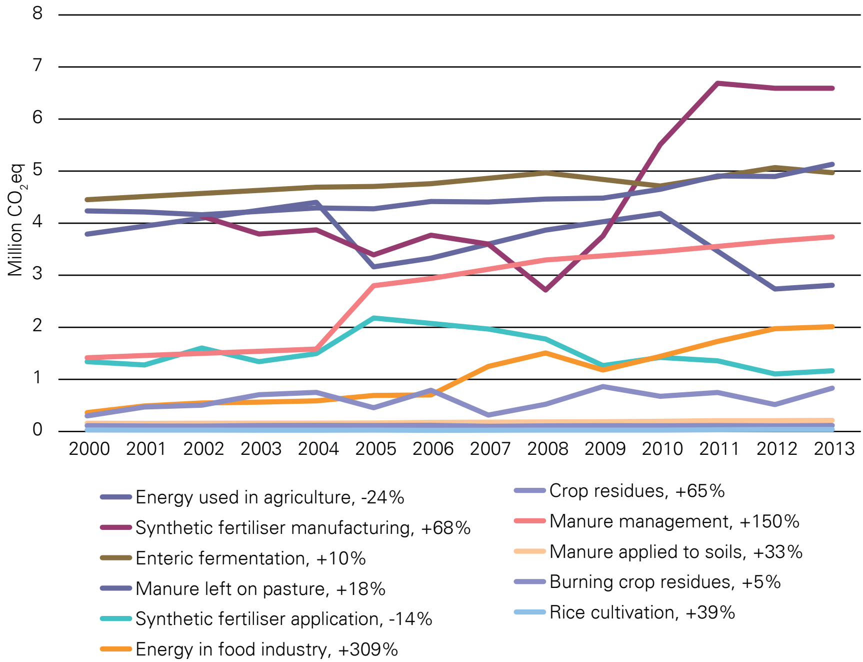
16 Despite being out of the scope of this section, this could also prove potentially very useful in assessing whether the country is on track to meet its GHG emissions reduction targets.

17 National accounts time series for energy consumed in the food industry start in 2007.

18 Synthetic fertiliser application is one of the categories that countries report to the UNFCCC according to IPCC 2007 Guidelines. GHG emissions from synthetic fertilisers consist of nitrous oxide gas from synthetic nitrogen additions to managed soils.

19 These emissions are typically not measured by countries under the UNFCCC. They have been estimated by the project team on the basis of N, P and K fertiliser use as reported in FAOSTAT, and we have applied a technical coefficient per unit of nutrient in fertilisers, just to complement the analysis of fertiliser emissions. They are not a mandatory analysis according to the methodology document.

Figure 14: GHG emission trends in agriculture (including energy consumed on-farm and for fertiliser manufacturing) and the food industry in Morocco, 2000–2013



Source: FAOSTAT (2015) and national GHG inventory for agricultural emissions, including energy use in agriculture; IEA (2015); HCP (2015) and authors' calculations for energy in food industry and fertiliser manufacturing.

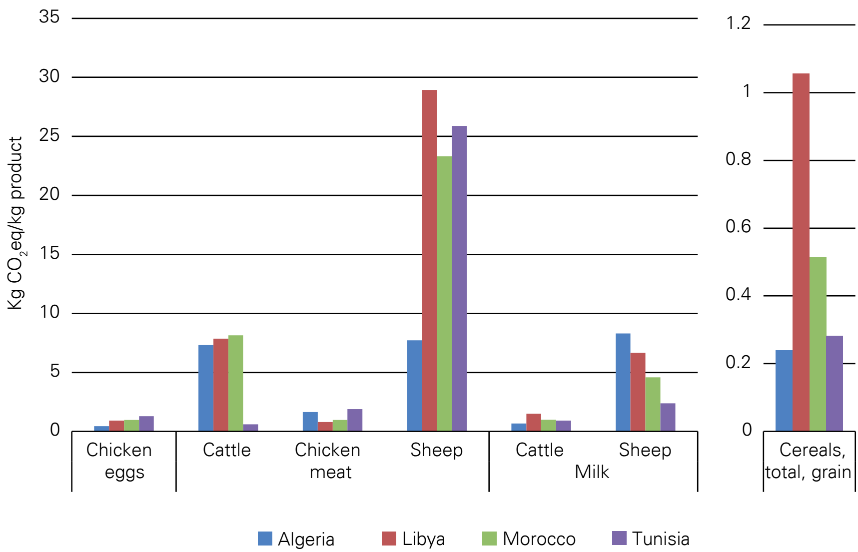
Note: Although GHG emissions from burning and rice cultivation are negligible or non-existent in Morocco, they are reported here for consistency with the IPCC Guidelines (IPCC, 2006). The measurement is done at Tier 1. The term "agriculture" here refers to the subsectors "crops" and "livestock".

GHG emission intensity

A third analysis useful to identify the agricultural activities that could be prioritised to reduce GHG emissions from the sector relates to the GHG emission intensity (i.e. total emissions per unit of product) of key commodities produced in Morocco compared to those same commodities produced in benchmark countries. On the basis of FAO estimates, a comparison is made between the GHG emission intensities associated with key commodities (i.e. meat, cereals, rice, milk and eggs) in Morocco and neighbouring countries.

The analysis is based on FAOSTAT data, since this ensures the application of a common method – based on IPCC 2006 Guidelines at Tier 1 – to all countries. The general conclusion that can be drawn is that Morocco has slightly higher emissions per unit of cattle meat produced when compared with other Maghreb countries, but its GHG emission intensities are within the region's average for all the other considered commodities. This confirms the importance of the livestock sector as a priority sector to mitigate agricultural emissions in Morocco.

Figure 15: GHG emission intensity of key agricultural commodities, 2012



Source: FAOSTAT, 2015.

Results of Step 1

The three analyses help depict the most relevant GHG emitting activities (and related GHGs) in the agrifood sector for Morocco. The conclusions are summarised in Table 3.

Table 3: Ranking of key emitting activities in the agrifood sector in Morocco on the basis of the three analyses done in Step 1 (GHG shares, trends and intensity analysis)

Key emitting activity	Reason	GHG targeted
1. Manure management	Manure management-related emissions are the most relevant in relative terms (i.e. much higher share than in the benchmark region) and their trend has been on the rise (+150% in 2013 compared to 2000). At the same time, GHG intensity of cattle meat production is high.	CH_4, N_2O
2. Manure left on pasture	The share of emissions from manure left on pasture is lower than in the benchmark region, although it still contributes an important and growing share of total agrifood emissions in the country (+18% in 2013 compared to 2000). The emissions contribute significantly to the high GHG intensity of cattle meat production.	N_2O
3. Energy use in agriculture	The share of emissions from energy used in agriculture is similar to the share of the benchmark region; their trend increased until 2010, followed by a slight decrease (maybe due to statistical reporting).	Mainly CO_2
4. Energy use in food processing	The share of emissions from energy used in food processing is slightly smaller than in the benchmark region, however their trend is on the rise (although actual data are uncertain).	Mainly CO_2
5. Enteric fermentation	The livestock sector is a major emitter in Morocco but the emissions share from enteric fermentation is lower than in the benchmark region. The emission trend is slightly increasing (+10% in 2013 compared to 2000). GHG intensity of cattle meat production is high and enteric fermentation is an important contributor.	CH_4
6. Synthetic fertiliser use (both application and manufacturing)	Emissions share from synthetic fertiliser application (nitrous oxide due to application on the field) is similar to the benchmark region, although on a decreasing trend. However, the amount of fertiliser used is increasing, resulting in more emissions associated with its manufacturing (carbon dioxide due to fossil fuel use).	Mainly N_2O and CO_2

Source: Authors' compilation.

On the basis of the above, these emitting activities can be considered intervention priorities from a purely GHG emission reduction point of view. It should be stressed that a large part of this analysis is based on a combination of the estimated GHG emissions done at Tier 1 by FAO, data reported by different bodies in Morocco to international organizations and official national communication to the UNFCCC. These data can provide a good indication but not all of them are verified and they should therefore be treated with care.

These findings are in line with the recent national determined contribution (NDC)[20] to mitigate and adapt to climate change indicated by Morocco to the UNFCCC, where it is stated that the main sectors covered will be (i) enteric fermentation, (ii) manure management, (iii) cropping systems (together with land use) as well as emissions from (iv) the energy sector, which includes agriculture and the agrifood industry. On the basis of the conclusions of Step 1, a number of technologies and practices are selected and assessed from a techno-economic point of view in Step 2.

Finally, it should be stressed that Step 1 does not consider emissions related to land use and land use change. The technologies considered focus on reducing emissions based on current land use. However, the carbon sequestration benefits of different options are considered in Step 2 of the methodology when relevant.

20 For more information, please see Morocco INDC, 2015.

Step 2: Prioritising climate technologies and practices based on costs, markets and technical information

The technologies and practices addressed in this study were selected on the basis of both the results of Step 1, which highlight the most critical agrifood activities in terms of GHG emissions (excluding land use) and a number of meetings with local stakeholders, mainly government representatives[21].

The technologies and practices considered can be called "climate technologies" since they are expected to reduce GHG emissions with a high level of confidence. Table 4 includes a more precise definition of these technologies as well as the rationale for their selection. Other technologies such as innovative greenhouse technologies (IGTs), solar dryers or cooking equipment were considered at an initial stage but then excluded due to their lower relevance for the Moroccan agrifood sector.

Certain technologies and practices refer to specific steps of the agrifood chain, while others are cross-cutting across agricultural and livestock production and food processing (Figure 16).

21 These meetings took place during the first mission in Morocco (November 2015).

Table 4: Selected climate technologies and practices able to tackle directly the agrifood activities identified in Step 1

Climate technology	Description and rationale for selection	Relevance for agrifood GHG emitting activity
Conservation agriculture	CA practices as defined in the methodology document[22] can increase the efficiency of resource use in agricultural crop production (time savings, lower labour requirements and reduction in fuel and machinery operations and maintenance [O&M] costs), result in improved long-term soil health and productivity (organic matter increase, in-soil water conservation and improved structure) and have significant environmental benefits including carbon sequestration.	**Energy use in agriculture:** reduced tillage leads to lower GHG emissions from fuel powering agricultural machinery. **Synthetic fertilisers:** the use of fertilisers decreases with direct seeding. The practice has important mitigation co-benefits in terms of carbon sequestration in the soil.
	In Morocco, CA is usually only implemented partially: a key pillar of CA – ensuring permanent soil cover especially by crop residues – is indeed difficult to do locally due to widespread non-conservative agronomic practices related to the management of crop residues. The crop residues are in fact exported outside the fields and/or consumed on site as pasture. Moreover, another practice representing a key feature of CA – diversifying and rotating crop varieties – has been gradually abandoned over the past 30 years (Bourarach, 1998)[23]. For these reasons, full application of CA in all the three key dimensions is difficult with Moroccan farmers that normally adopting direct seeding, hence the practice assessed in this study focuses on direct seeding	
Efficient field machinery	Efficient field machinery management is a mixture of technology and improved practice. The focus is on changes that can be produced by both energy efficiency testing of tractors and the training of tractor users so as to induce: (i) tuning and repair of agriculture tractors that are over 5 years old (currently about 30% of total national tractor fleet, i.e. 19 200 units); (ii) more efficient driving; (iii) improved machinery management and working organization at field level; (iv) an adequate setting and maintenance of support tools; (v) the optimisation of transport and refuelling; and (vi) optimised timing for operations (based on soil conditions, stage of maturity and cultures, etc.).	**Energy use in agriculture**: efficient tractors and efficient management of them decreases GHG emissions associated with fossil fuel burning.

Climate technology	Description and rationale for selection	Relevance for agrifood GHG emitting activity
Drip irrigation	While the increase of the area under drip irrigation may increase water use efficiency, the impact on energy consumption is mixed. Most benefits in terms of energy consumption and GHG emission reduction are associated with replacement of surface irrigation (as opposed to sprinkler irrigation) when water pumped from a static lift is equal or superior to 10 m. Under these conditions, drip irrigation can be considered a GHG-saving technology. In addition to energy savings associated with water pumping, drip irrigation might bring savings on fertiliser use and thus on emissions for its production and transport. However, these vary greatly depending on the production system and are not accounted for in the estimate of the potential to reduce GHG emissions.	Energy use in agriculture: replacing the water use method reduces energy consumption, translating into a GHG emission reduction.
Solar/wind-powered water pumping	Solar photovoltaic (PV) generators and wind turbine-powered electric pumps can be used as an alternative to fossil fuel or grid electricity-powered water pumps in irrigation. In the case of pressure irrigation, the wind and/or PV system needs to continuously power the irrigation system, which relies on a battery, the national grid or fossil fuel backup. Alternatively, the water can be stored in a tank or reservoir to be used in low pressure or gravity irrigation systems. In this study, solar/wind-powered water pumping without energy storage (e.g. batteries) is considered an alternative to on-grid and off-grid pumping.	Energy use in agriculture: pumping for irrigation can be powered by renewables therefore avoiding GHGs associated with electricity generation and fuel burning.
Grazing management	In Morocco, ruminants exist mostly in traditional extensive systems comprised of free-range grazing land, meaning that changes in grazing management can potentially affect a large percentage of the national herd. Grazing management comprises a set of technologies and practices that includes rotational (i.e. multi-paddock) grazing, improved fauna of grasslands, protective infrastructure (e.g. against weather conditions, inland inundation, predators, theft), or shortened walkways from shelter to grazing area. Many of these contribute to climate change mitigation by: (i) reducing emissions per unit of production (sustainable intensification of production); (ii) decreasing methane emissions of livestock enteric fermentation (improved digestibility) or (iii) increasing carbon sequestration of soils (improved vegetation of grazing land). Documented projects in Morocco introduced practices such as improved vegetation, soil cultivation, plantation of shrubs, rotational grazing, fencing, establishment of grazing bans and the installation of shelters on land area used to feed grazing livestock. There are several other grazing management techniques considered in international literature, such as fertiliser application, shortening of walking distances to the field, creating mobile drinking stations, irrigation, reduced grazing in wet seasons, and extended or reduced period of grazing season, that have not been not tested in Morocco and are considered in this study.	Enteric fermentation: properly managed pastures allow the production of more digestible feed targeted to animal needs, thus reducing enteric fermentation CH_4 emissions. Synthetic fertilisers (application and manufacturing): sustainable intensification can lead to less input per unit of feed, however the real effects can vary and therefore fertiliser emissions are not assessed. A major co-benefit is carbon sequestration in the soil associated with pasture management on degraded land.

Climate technology	Description and rationale for selection	Relevance for agrifood GHG emitting activity
Manure as soil amendment	This practice could be put in place in cases of geographically concentrated livestock herds of cattle, sheep and goats. It is in fact a mixture of good management practice for manure and the introduction of new technology to store and treat the manure. More specifically it would focus on: (i) increasing the frequency of manure removal and (ii) preventing leaching and volatilisation from manure (e.g. sealed storage for methane collection, stacked manure storage replacing slurry storage, burning of accumulated methane). Additionally, all the collected manure can be processed into biogas and its resulting digestate (biogas is addressed as a distinct technology) or into soil amendments (chiefly compost) through more direct conversion processes (e.g. thermal treatment). The additional manure mobilised for soil fertilisation through composting can thus potentially offset the use of synthetic fertilisers and avoid emissions related to their production[24]. However, given that most of the manure in Morocco is already applied to the soils, it is not clear how much synthetic fertiliser can be actually displaced, although manure treatment will bring additional benefits in terms of soil fertility or herbicide and pesticide applications.	Manure management: improved management technology and practice can decrease CH_4 and N_2O emissions by up to 30%. Synthetic fertilisers (manufacturing): compost can displace synthetic fertiliser use thus reducing the emissions associated with their production (regardless of the actual country where fertilisers are manufactured).
Livestock dairy breeds on improved diets	Dairy farming in Morocco is mostly undertaken with highly productive dairy breeds such as Holstein and crosses between these breeds and local ones. Local breeds contribute only marginally to the overall milk production. The options available for reducing enteric emissions per kilogram of milk imply improving milk productivity by ameliorating feeding conditions and continuing to move from crossbred cattle to highly productive dairy breeds. Ruminants' diets can be improved directly or indirectly. Direct interventions are better fodder fed to the livestock, while indirect interventions are achieved by improvements for grazing herds, usually by enriching the grazed plant mix, extending grazing seasons, switching between crops grown as fodder, or building irrigation systems on pastures. This assessment deals with fodder fed to the livestock.	Enteric fermentation: CH_4 emission reduction in absolute terms are negligible (or even negative). However, the GHG intensity for cattle products improves significantly. Manure applied to soils: improved diets not only decrease enteric fermentation emissions but potentially reduce grazing times, hence N_2O emissions from manure left on pastures. Manure left on pasture: improved livestock breeds are usually associated with less extensive systems. This indirect effect on emissions from manure left on pasture is not assessed.
Efficient water boilers	This technology focuses on small and medium water boilers used in the agrifood industry (not exceeding 2 tonnes per hour of steam) which represent the vast majority, and on the energy efficiency gains that could be achieved by refurbishing old boilers and substituting them with new ones. These boilers usually run on fuel oil. The sugar industry is left out of the assessment since it is assumed it typically makes use of large and already very efficient water boilers[25].	Energy in food processing: energy efficient boilers lead to less fossil fuel consumption (typically fuel oil) hence GHG emissions.

Climate technology	Description and rationale for selection	Relevance for agrifood GHG emitting activity
Efficient cold storage	Although it avoids losses of perishable food, thus reducing the food carbon footprint, the cold chain itself is a major emitter due to its intensive energy demand. The food cold chain is responsible for nearly 1% of the world's GHG emissions (James & James, 2010) and around 16% of the energy consumed in the food processing industry (FAO and USAID, 2015). As the energy demand for cooling increases with ambient temperatures and sunny hours, Morocco's energy bill to power its total capacity in cold warehouses is quite high[26]. This assessment focuses on energy efficiency measures to reduce electricity consumption of food cold storage. It assesses the most economically viable measures advised by the International Association for Cold Storage Construction (IACC, 2011) and the European Commission's *Improving Cold Storage Equipment* project (ICE-E, 2010) as practices to start with when targeting energy efficiency. Combined, such measures can result in a more than 50% reduction of refrigeration energy requirements. In fact, refrigeration and lighting account for 40–60% and 10–25%, respectively, of the energy consumption of cold storage (ICE-E, 2010). Evaporators, compressors and condensers used in refrigeration can have their energy consumption reduced for example through the installation of variable frequency drives (VFDs), fast doors with improved sealing, and improved warehouse wall insulation. Lighting consumption can be reduced by switching to energy saving bulbs. The section on economic and financial attractiveness gives specific actions, but the chosen retrofitting measures for analysis can be summarised as follows: (i) improve part-load performance by installing VFDs to evaporators, compressors and condensers and repair compressed air leakages; (ii) introduce fast doors with better sealing; (iii) create energy savings through enhanced energy management and installation of LED lighting; (iv) improve warehouse wall insulation.	**Energy in food processing:** energy efficient cold storage for food leads to less electricity consumption hence reduced GHG emissions associated with electricity generation.

Climate technology	Description and rationale for selection	Relevance for agrifood GHG emitting activity
Biogas from manure and agri-residues	Anaerobic digestion allows the conversion of agricultural residues like animal manure into biogas, which can be used for direct combustion or to generate electricity and/or heat, therefore avoiding GHG emissions from aerobic fermentation and at the same time providing an alternative to fossil fuels. In addition, anaerobic digesters can eliminate the flow of lethal microorganisms such as *E. coli*, *faecal streptococcus*, Krohn's disease and Johnes disease which, if not managed properly, can infect cattle and humans. On farms with anaerobic digestion systems, the digestate separated from the solid content of the manure can be dried and used directly as fertiliser, or it can be separated into its solid and liquid components to be further processed into valuable co-products. In Morocco, the major form of RE is biomass, mostly in the traditional form of fuel, firewood or charcoal for heating and cooking purposes. Biogas in Morocco is mainly limited to biogas recovery projects such as in the Agadir, Fes and Marrakech water treatment plants. Biogas from agri-residue technology was introduced in Morocco in the early 1980s by installing digesters in use for R&D or demonstration projects. These experiences focused on small biogas digesters suitable for smallholders without commercial applications and their introduction was largely supported by international cooperation. Chinese and Indian digesters were mostly used. The effectiveness of this kind of intervention is doubtful as reported by local experts. In fact, among the few hundred household digesters installed, only dozens remained operational after some years.	Manure management: CH_4 and N_2O emissions from manure are reduced as a consequence of the anaerobic treatment. Crop residues: N_2O emissions due to decomposition of crop residues are reduced as they are removed from the field to feed the biodigester. Fertilisers (application and manufacturing): digestate can displace chemical fertiliser use thus contributing to reducing emissions. However, this mitigation effect is not assessed here. Energy use on-farm and Energy in food processing: Biogas can be used for electricity and heat generation, thus directly displacing fossil fuel use and associated GHG emissions.
	These climate technologies focus however on commercial applications of biogas for power (heat and electricity) as an alternative to other energy sources, therefore smallholder applications are not considered. Moreover, since using dedicated energy crops like maize silage would have implications for land use, compete with food or fodder production and weaken financial returns, only agri-waste, crop residues and manure are considered as potential feedstock.	
Renewable energy systems	Morocco is endowed with considerable RE resources, in particular solar and wind. Liquid biofuels are not a common source of energy in the Moroccan agricultural sector and therefore are not taken into consideration in the context of the present study. Biogas from agricultural residues is addressed separately. This climate technology includes a group of technologies applicable to the agrifood sector, namely: - PV systems which convert sunlight into electricity - solar water heaters which use sunlight to heat stored water - wind systems to produce electricity - The focus is on on-grid RE applications, satisfying energy needs of farms or agribusinesses.	Energy use on farm and Energy in food processing: RE production directly displaces fuel or electricity consumption, hence GHGs associated with fossil fuel burning.

Climate technology	Description and rationale for selection	Relevance for agrifood GHG emitting activity
Small dams	A small dam, under Moroccan nomenclature, is a small reservoir with a height ranging from 10 to 25 m, and low storage capacity (usually between 0.5 and 2 million m^3). The watershed controlled by a small dam often varies from 0.5 to 5 km^2. Small and medium dams made in Morocco are relatively higher than the average in other countries due to the country's steep slopes and complex geology associated with land degradation and limited permeability, allowing floods and amplifying their peak flow, and secondly by a warm climate favouring evapotranspiration associated with irregular water conditions (CMB, 2010). Small dams are effective solutions for a number of issues in agriculture in Mediterranean climates. They are primarily used for irrigation during the dry season and the pre-rainy season as they may enable the establishment of food and cash crops that could not be undertaken relying upon variable stream flows. They can also be used, either separately or combined, for fish farming, livestock and domestic water supply, drainage sumps, groundwater recharge, flood control and conservation storage (FAO, 2010b).	**Energy use in agriculture**: energy (electricity) consumption that would be needed to pump water from the underground in arid areas can be avoided thanks to small dams for water catchment, thus reducing GHGs associated with electricity generation.

Source: Authors' compilation.

22 CA is a set of integrated, environmentally-friendly, agricultural principles and practices that minimise disruption to the structure of the soil, nutrient value and natural biodiversity. Practices include: (i) minimal mechanical soil disturbance; (ii) permanent organic soil cover; and (iii) diversification of crop species when grown in rotations and/or associations.

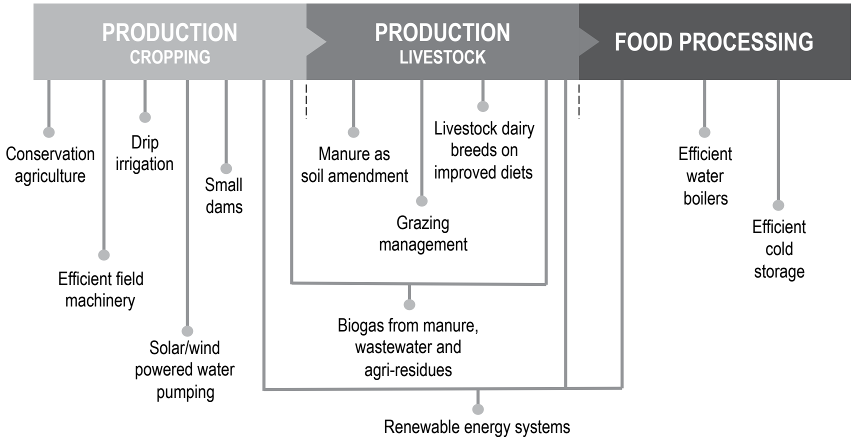
23 This was mostly due to high labour costs for legumes, a low level of mechanisation, and widespread utilisation of mineral fertilisers (at least in some areas) (Boughlala et al., 2011). The reduction of oilseeds as a result of trade liberalisation and an organised and subsidised cereal value chain are factors that may have also contributed to a decrease in rotations.

24 The results of assessments on the use of composting as a GHG mitigation technology are mixed. According to FAO (2013b), "composting of animal manure causes significant N and CO_2 losses, but the benefits of reducing odour and CH_4 emissions, compared with anaerobically-stored manure, make it a recommended GHG mitigating option. Nitrogen losses, predominantly as NH_3 but also as N_2O, however, are large". Other benefits of using compost rather than synthetic fertilisers are due to the organic matter contribution and improved release time in the soil of the nutrients.

25 Moreover, the sugar industry relies largely on sugar processing by-products for energy (e.g. bagasse), which would further complicate the assessment.

26 There are two sources of GHG emissions attributable to cold storage. The direct one is the leakage of refrigerants. The phasing out of hydrochlorofluorocarbon (HCFC) refrigerants with extremely high global warming potential (GWP) is governed by the Montreal Protocol, while the gradual phase out of hydrofluorocarbon (HFC) refrigerants with lower (albeit still high) GWP levels by replacing them with environmental friendly substances (CO_2, NH_4, etc.) is addressed by the Kyoto Protocol. The second and indirect source of emissions originates from energy spent on powering the cold stores. This can be tackled either through energy efficiency improvement measures or the use of renewable energy sources like solar photovoltaic, wind or biogas. Generating cold for storage is also a good fit for distributed PV generation, as the demand is higher when the sun shines the most.

Figure 16: Technologies and practices considered and the different stages of the agrifood chain



Source: Authors' compilation.

Step 2 of the methodology consists of a techno-economic assessment of the technologies considered, following a multi-criteria analysis (MCA) approach. As illustrated in detail in the methodology document, the MCA is used here to assess the investment priorities in climate technologies/systems in order to optimise mitigation efforts. The MCA approach (of Step 2, then complemented by Step 3) enables an assessment of performance measures, socio-economic costs and co-benefits, and promotes the participation of local stakeholders in prioritising mitigation efforts. The approach is designed to compare a mitigation option to a reference case or to a set of alternative measures, primarily ex-ante. The MCA method can accommodate a range of measures even if they are hard to quantify or monetise. It also allows the integration of cost-benefit analyses where sufficient data are available.

The MCA method involves developing a set of criteria, both qualitative and quantitative, by which the range of mitigation technologies, systems and practices can be assessed and compared for their mitigation potential. The criteria (and indicators) used in this assessment are reported in Table 5. Each criterion is given a rating score and then assigned a weighting value to reflect the relative importance of it in the specific country in question (Browne and Ryan, 2011).

The scores are based on estimates by several experts or on objective measures. Weights were also assigned to the criteria and discussed at a stakeholder workshop organized in March 2016 where initial results were presented. Weights are then used to aggregate the results of Step 2 into one single techno-economic score by technology.

Table 5: Criteria and indicators used in Step 2

Criterion score	*	**	***
Technical criteria			
Performance compared with international best practice	The most efficient technology is not available.	The most efficient technology is available but costly.	The most efficient technology is commonly available.
Maturity of technical support services	Technical support services do not exist or are at a very early stage and cannot support the uptake of the new technology/ practice; and the degree of technical knowledge is at a very early stage. The majority of operators do not know how to use the technology.	Technical support services exist but are not fully widespread and/or not fully efficient. In particular, they are not able to support the diffusion of the technology. The degree of technical knowledge is still at an early to intermediate stage with many operators not able to use the technology to its full potential.	Technical support services are widespread and efficient; and the degree of technical knowledge is such that most operators can use the technology to its full potential.
Potential to reduce annual GHG emissions	The technology/practice capacity to reduce annual national GHG emissions by the agricultural sector is less than 3%.	The technology/practice capacity to reduce annual national GHG emissions by the agricultural sector is between 3% and 10%.	The technology/practice capacity to reduce annual national GHG emissions by the agricultural sector is more than 10%.
Market criteria			
Current technology adoption rate	Technology market penetration or adoption of the practice is high, leaving little space for improvement.	The market for the technology or adoption of the practice is mature but there is still space for marginal improvements and small increases (possibly with reduced risk and limited profit).	The technology is in a growing phase but with market share still much reduced. Few innovators have adopted the practice.
Trends in gap between current technology uptake and technical potential	The gap is small and stable or reducing over time.	Relevant but reducing over time.	The gap is large and has been increasing in recent times.
Economic criteria			
Financial attractiveness	fIRR < 12%, or Payback time > 8 years	fIRR 12%-20%, or Payback time 3-8 years	fIRR >20%, or Payback time 0-3 years
Mitigation cost	Positive mitigation cost	Between USD 0 and -20 per tCO_2eq avoided	< -20 /tCO_2eq avoided
Data availability	Indicators based on ad hoc surveys or research: data are collected in the field by inspection of installations, undertaking surveys of equipment suppliers, analysing financial investments, etc.	More disaggregated indicators: data is sourced from a number of other sources, often of specialised nature, e.g. from organizations that certify boilers or associations that import tractors.	High-level indicators: data are normally sourced from statistical offices or other official national or international data sources and not always easily disaggregated to the required level of detail.

Source: Authors' compilation.

A number of technical coefficients and reference prices were used for Morocco in order to compare technologies and practices on a common base. These values are reported in Annex 1.

To assess the economic criteria consistently, a financial discount rate of 12 percent and a social discount rate of 8 percent were adopted (for a summary discussion on the choice of the discount rate see Box 1). The gap between the two rates reflects a greater opportunity cost of capital for private investments when compared to social. The financial discount rate is used for the calculation of financial returns of adopting the technology/practice and the social discount rate for the economic analysis associated with estimating mitigation costs. The analysis associated with the scores assigned to each criterion is reported below by technology/practice.

Box 1: Elements in choosing a discount rate

Several factors should be taken into account when choosing an appropriate discount rate for investment in key sustainable climate technology in the agrifood sector. The cost of capital in Morocco can be extrapolated from different sources:

- the government bond coupon in 2012 was around 4.5-5.5 percent (World Bank, 2015a; Cbonds, 2012);
- the lending interest rates in 2015 were between 5 and 7 percent (Morocco's Central Bank: Bank al-Maghrib, 2016);
- the central bank's official interest rate until late 2014 was 3 percent, and it is currently 2.5 percent (Bank al-Maghrib, 2016);
- the interest rate average spread (b/w loans and deposits) in 2014 was 4.1 percent (IMF, 2016);
- the deposit interest rate in 2014 was 3.9 percent (Trading Economics, 2016);
- the weighted average cost of capital (WACC) for the food and beverage sector in Morocco is estimated to be 10.55 percent (WaccExpert, 2016).

In addition to the cost of capital, the discount rate should take into account the risk or uncertainty of future cash flows, so it should include the so-called "country risk premium", which for Morocco is between 2 and 3 percent. Moreover, investments in the agricultural sector may imply a further risk component. For instance, International Renewable Energy Agency (IRENA) (2016) adds to the discount rate a technology-specific risk premium of 2 percent for nuclear, 2.5 percent for offshore wind and concentrated solar power, and 3 percent for less mature technologies. In this study, we apply a unique discount rate for all practices/technologies, but we take into account the increase in risk connected to the agrifood sector.

For evaluating projects in Morocco, the World Bank has recently adopted different rates: a 12 percent internal rate of return (IRR) as benchmark for the assessment of regional irrigation modernization projects (World Bank, 2015b, Annex 5); a 10 percent discount rate for the economic analysis of water project in rural areas (World Bank, 2014); and a 6 percent discount rate for a clean and efficient energy project in 2015 (World Bank, 2015a).

Analysis by technology/practice

Conservation agriculture

Table 6: Summary of the techno-economic criteria scoring for CA in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
**	**	***	***	***	***	**	**

Source: Authors' compilation.

As mentioned in the previous section, in this assessment we assume that CA in Morocco is applied mainly through direct seeding (no-till) in an attempt to ensure a minimum of permanent crop cover. Seeding without ploughing/tillage and seedbed preparation requires seed drills to: (i) cut through crop residues; (ii) penetrate the soil (also compacted soils) to the optimum seeding depth; and (iii) place seeds and fertiliser accurately, closing the furrow, and ensuring good soil-to-seed contact. Undisturbed soils are denser and tougher to penetrate. Also, presence of stubble on the soil surface adds another layer of obstacle for seeding. For these reasons, most no-till seed drills are heavier than conventional ones. The technical recommendation by the *Institut national de la recherche agronomique* (French National Institute for Agricultural Research [INRA] and *Institut Agronomique et Vétérinaire* (IAV) is the use of tractor-mounted drills, with working widths between 2 and 3 m, adapted to the most commonly utilised tractors in Morocco (70–90 CV).

Technical assessment

Performance compared with international best practice

Criterion score: **

As discussed above, CA in Morocco is assumed to not be applied fully in all its dimensions and therefore some of its potential for GHG emission reduction is not attained. The level of GHG emissions reduction estimated for Morocco is 630 kg CO_2eq/ha (see more below) with full CA adoption and includes soil carbon sequestration and fuel associated emissions reduction. Soil carbon stocks and mitigation potential depend on the agroclimatic zone and the land use type and intensity. The rate of soil organic matter decomposition and turnover depends on many factors and is affected by land use and management (particularly mechanical soil disturbance). In degraded soils (like many of Morocco's soils), carbon sequestration has the highest potential, but it is a slower process to start, because the soil microbial population requires specific nutrient ratios that take time to achieve. In addition, the ability of these soils to maintain carbon over time is uncertain.

Maturity of technical support services

Criterion score: **

There has been good progress on developing local direct seeders with new models being tested. Full industrialisation at the local level is still underway. On the other hand, the import and distribution system of agricultural equipment is well functioning and there is already a number of cases of importing direct seeders that use Spanish and German technology, as well as Brazilian (SEMEATO) and Moroccan seeders (SAT, 2000). The deployment of the practice does require some skill given that it involves major changes to farming practices and there is a lack of experience in this practice, especially among farmers. Examples of adoption of the technology have required significant extension support. Technical assistance is still needed as a means to overcome possible errors in the selection, implementation and uptake of this technology.

Given the stage of mechanisation of Moroccan agriculture there is already a good network of repair shops and support services used for conventional farming machinery (including seeders) that can easily also support repairs of CA equipment. There has been some degree of research and development (R&D) to tailor direct seeders to local circumstances (soils and average tractor size) and reportedly the key technical obstacles have been surpassed. Still, it should be noted that for those willing to import seed drills (namely from Europe) there remain issues of compatibility; for example, such equipment is not always adapted to the typical tractor size in Morocco, which tends to be of lower power in the case of smallholders.

Potential to reduce annual GHG emissions

Criterion score: ***

Empirical evidence confirms that in the Moroccan context, adoption of CA can have a positive impact on GHG emissions reduction[27]. The adoption of CA

27 CA contributes to the mitigation of greenhouse gases since, by eliminating tillage practices, the soil is converted into a carbon sink/pool. Under CA, a shift occurs from accelerated soil degradation due to tillage intensity to an improvement of soil, water, air resources and biodiversity. Micro-organisms make up the largest share of living biomass, followed by earthworms and other animals which are present in the soil fauna. The latter are largely responsible for the correct functioning and stabilisation of soil systems due to a number processes that are a fundamental element of soil dynamics, i.e. decomposition of plant residues, humidification, mineralisation, nitrification, biodegradation, soil aggregation and others. CA can indeed contribute to the sustainable management of soil systems. In contrast, conventional practices lead to the degradation of soil fertility, reduced biodiversity and accelerated soil erosion, requiring major energy use and reducing the opportunity to set up crops in favourable conditions (Friedrich et al., 2011).

practices over large areas of land would allow for a significant reduction in fuel consumption and consequently in CO_2 emissions, making agriculture a major contributor to global GHG emissions reduction. Carbon sequestration can also play a big role in reducing emissions in the long run if CA is practiced over time (Mrabet, 2008).

Emissions from energy use in agriculture decrease with CA due to lower fuel consumption (which can be quite high with conventional ploughing and cultivation). In Morocco, this is estimated at around 30 litres of diesel per hectare: the difference is approximately 50 litres/ha/year in conventional practice and 20 litres/ha/year under CA[28], leading to a potential saving of roughly 80 kg CO_2eq/ha/year. This estimate is more conservative than the one suggested by the report on the Project of Integration of Climate Change in the *Plan Maroc Vert* (*Projet d'Intégration du Changement Climatique dans la Mise en œuvre du Plan Maroc Vert,* PICCPMV) of 120kg CO_2eq/ha (NOVEC, 2013).

In addition, according to Moroccan experts' opinions, switching from conventional practices to CA (as it is defined in the local context) would result on average in roughly 150 kg C/ha (or 550 kg CO_2eq) of annual GHG sequestration. This estimate is quite conservative and below the 250 kg C/ha which was used for similar FAO assessments of CA in Morocco (Sutter, 2012). Overall, international empirical research points to a broad range of carbon sequestration possible through CA adoption depending on many conditions. For example, the PICCPMV report for phase 2 estimates that CA adoption can lead to around 1 400 kg CO_2/ha/year of emissions reduction (NOVEC, 2013).

Moreover, according to the report on the PICCPMV, there are some 1.1 million ha of land to be potentially converted from conventional to CA in the country if one only focuses on the areas with the greatest potential (NOVEC, 2013). According to the assessment conducted by FAO (Sutter, 2012) on the carbon balance of the PMV Roadmap Strategy, the areas where improved agronomic practices and CA can be implemented total almost 1.5 million hectares of cereals, leguminous and oilseeds crops (the areas considered in the study include both cropped and intercropped areas). This could rise up to 3 million ha (i.e. some 30 percent of total utilised agricultural land), if some practical constraints impeding the adoption of CA are overcome (NOVEC, 2013 and discussions with local experts). Finally, according to the same report and discussions with local experts[29], the full technical potential for the country is estimated at 5 million hectares, which would represent practically all the land dedicated to cereal-based systems in Morocco. These estimates do not take

28 From discussions held with agronomists and soil scientists Dr. Benaouda and Dr. Balaghi (INRA) as well as Dr. Bourarach (mission of 9-13 November 2015).

29 Ibid.

into account the potential for introducing CA in fruit tree systems, which could also be targeted.

Overall in this report we assume a range from 1.1 million hectares of immediate potential land (just focusing on those areas where adoption would be easiest) to 5 million hectares of full technical potential. According to the PICCPMV second phase study (NOVEC, 2013), the regions with greatest immediate potential would be *Doukkala-Abda* (430 000 ha) and *Chaouia Ouardigha* (378 000 ha).

As can be seen in Table 7, the estimates for total GHG emissions reduction potential in Morocco from the adoption of CA, including the carbon sequestration benefit, are in the range of 691 thousand to 3.2 million tCO_2eq/year. Considering just the emissions from energy saved and the most positive technical potential, this corresponds to 1.7 percent of total agrifood emissions – which would go up to 13.4 percent if the benefits from carbon sequestration in the soil are included. An additional mitigation benefit that is not considered here is the lower amount of fertiliser used over the years.

Table 7: Scenarios for technical potential of adoption of conservation agriculture in Morocco and estimates of GHG emissions reduction

Technical potential scenarios	Estimated GHG emissions reduction potential		
	Fuel savings	Carbon sequestration	Total
(million hectares)	(thousand tCO_2eq/year)	(thousand tCO_2eq/year)	(thousand tCO_2eq/year)
1.1	86	605	691
3	234	1 650	1 884
5	397	2 750	3 141

Source: Authors' calculations.

Market assessment

Current technology adoption rate

Criterion score: ***

CA was first introduced in Morocco by the Imperial Chemical Industry[30] (temporary importation of a seeder) in the 1970s. However, scientific studies only started in the 1980s in Settat (INRA) (Bouzza, 1990; Ouallali, 1987; Dahane, 1992; Nousfi, 1993) through cooperation between USAID and INRA and then in the Zaer region (IAV Hassan II) (Bourarach, 1989; Bourarach, 2001). Systematic

30 The Imperial Chemical Industry was a pioneer of zero tillage in the 1970s in the UK where they developed direct drill seeders.

trials in real farm conditions started only in 1997 (El Brahli et al., 2009). In spite of the largely recognised agronomic (Bourarach, 1989; Bouzza, 1990; Mrabet, 2002), ecological, economic and technical benefits (Bourarach, 1989; Boughlala et al., 2011) CA technology has barely progressed in the past 15 years.

Currently, the no-till planted area is estimated at 12 000 ha (according to INRA) although some stakeholders claim it may even be as little as 2 000 ha. According to the study by ADA linked to the PICCPPMV project (ADA, 2013) the area at present is around 4 600 hectares, mostly located in the Chaouia Ouardigha region. This is well below the estimated conservative immediate potential of 1.1 million ha (or just 0.4 percent if we assume 4 600 ha at present), and the more optimistic scenario of 3 million ha or even full technical potential of 5 million ha. In any case, the technical market potential is largely untapped.

Trends in the gap between current technology uptake and technical potential

Criterion score: ***

The reduction of land dedicated to cereal production through higher productivity and a focus on higher value-added crops for which Morocco has a comparative advantage may lead to a reduction of technically viable areas for CA adoption. For example, the PMV has targeted this approach from the start. This trend is, however, not expected to have a major impact at least in the short- to medium-term. In addition, it is also widely recognised that CA can be adapted to fruit tree plantations.

Most importantly, greater awareness at the political level combined with actions by the MAPM for both mitigation and adaptation to climate change are expected to lead to an expansion of CA in the coming years. For example, since 2013, the *Fonds de Développement Agricole* includes a specific subsidy for purchases of direct seeding equipment (in 2015, 1 unit was given per tractor with a subsidy equivalent to 50 percent of the sales price and a ceiling of MAD 90 000 or around USD 9 000 per unit). In addition, there has been renewed interest in the technology recently and, in particular, it has been piloted under the World Bank-supported project PICCPMV, which was led by ADA/MAPM.

While there seems to be increasing awareness and initiatives to foster CA adoption in Morocco, the analysis suggests that the gap between technology uptake and technical potential is relevant and has not been decreasing dramatically with the current market situation and policy mix.

Economic assessment

Financial attractiveness

Criterion score: ***

Financial costs and benefits

Empirical research undertaken in Morocco since the 1980s confirms international evidence that direct seeding can lead to an improvement in farming operating profit. Studies using data from research stations and real farming conditions indicate this is mostly a result of reduced labour costs, time savings due to limited operations required on the soil, reduced fuel costs, and increased yields (Bourarach, 1989; Boughlala et al., 2011).

The *Stratégie Nationale de Mécanisation Agricole* (National Strategy for Agricultural Mechanisation, SNMA) also confirmed this data and indicated that energy costs (especially diesel) place a heavy burden on farm budgets. For example, test plots evaluated during 2 years in the Gharb region showed that the fuel cost of a combination of disc ploughing as primary tillage and rotary cultivation for seedbed preparation results in around a 15-time higher fuel consumption in litres per hectare when compared to a direct drilling no-tillage system (Dycker & Bourarach, 1992). Moreover, data from a survey of 70 farmers carried out in 2011 in Morocco also suggest substantial cost reductions can be achieved through the introduction of no-tillage practices (Boughlala et al., 2011). The survey results are summarised in Table 8 and refer to bread wheat production costs across three regions (Zair-Rabat, Abda and Chaouia) for small, medium and large farms. The average farm size in the covered regions was 4.8 ha for small-scale farms, (representing about 61 percent of total farmers and over 31 percent of total area), 13.5 ha for medium-size farms, (25.6 percfent of farmers and 50.5 percent of the area), and 21.6 ha for large farms (13.5 percent of farmers but over 18.5 percent of the land). According to technical experts from Morocco, the three regions covered by the survey are deemed to be well representative of no-till systems in the country (i.e. they are the regions where no-till practices are implemented). The data using financial prices suggest that the adoption of no-till practices can reduce total production costs per hectare by 20 percent. The main driver of such a reduction is the cost of tillage (which is of course absent in the case of no-till) followed by the cost of seeds. On the other hand, no-till is expected to result in higher costs for some items, in particular herbicide, in the first years following adoption. Overall, substantial savings are reported in fuel costs per hectare (which are embedded in the different cost items of Table 8). More specifically, diesel consumption in conventional production systems is about 53 l/ha, compared to just 28.5 l/ha in no-till[31]. This

31 According to Boughlala et al. (2011), op. cit., the calculation of estimated savings in diesel was done only in the Chaouia region with a group of seven farmers that have their own machinery.

allows for a reduction of around 24 l/ha (somewhat lower than our average estimate of 30 l/ha for total GHG emissions reduction potential).

Table 8: Average estimated costs of production for bread wheat using conventional technology and no-tillage system for medium and large farms (excluding diesel costs)

Item	Conventional technology [a/]	No-till technology [a/]	Difference (CT-NT)	
	USD/ha	USD/ha	USD/ha	%
Seeds	77	64	-13	-17
Fertiliser	86	90	4	5
Tillage	83	0	-83	-100
Seeding	23	26	3	13
Herbicide	39	49	10	26
Fungicide	56	53	-3	-5
Custom combining	38	38	0	0
Hired labour	8	7	-1	-13
Family labour	10	9	-1	-10
Total costs	420	336	-85	-20

Source: Authors' calculation using Boughlala et al. (2011).

[a/] average from 3 regions.

In addition to the above, discussions[32] held with national experts suggest there are significant differences in estimates of potential cost reductions through introduction of CA practices in Morocco. More specifically, interviews indicate that decreases by up to 30 percent in fertiliser costs per hectare are possible due to a substantial reduction in quantities over time as soil health improves. According to some experts, seeding costs per hectare can also be reduced up to 38 percent, even considering that in direct seeding the additional cost of pre-emergence treatments is added. If there is late rain, the absence of pre-emergence treatments can allow for an up to 60 percent reduction in seeding cost per hectare.

32 Values of operating cost reductions due to introduction of CA practices in Morocco described in the paragraph below were obtained through interviews with experts held at INRA and the results of the PICCPMV evaluation.

Further to shorter-term cost reductions, CA practices are expected to have medium- to longer-term benefits in terms of yields (not only level but also sustainability). In fact, CA contributes to reducing compaction and soil erosion by reducing farm machinery traffic and keeping residues on the soil. Soil erosion may be reduced by up to 90 percent if full soil cover is maintained. Even in the case of modest coverage just above 30 percent, as is achievable in most instances in Morocco[33], substantial reductions in soil erosion are still possible (Friedrich et al., 2011). Furthermore, the CA practice of diversifying rotations also has a positive impact on yield levels and results in progressive reduction of fertiliser needs. All this is also noted as part of Step 3.

Financial returns

Given the data described above and additional information collected locally, a simple model of CA practices in Morocco was built with the following key parameters:

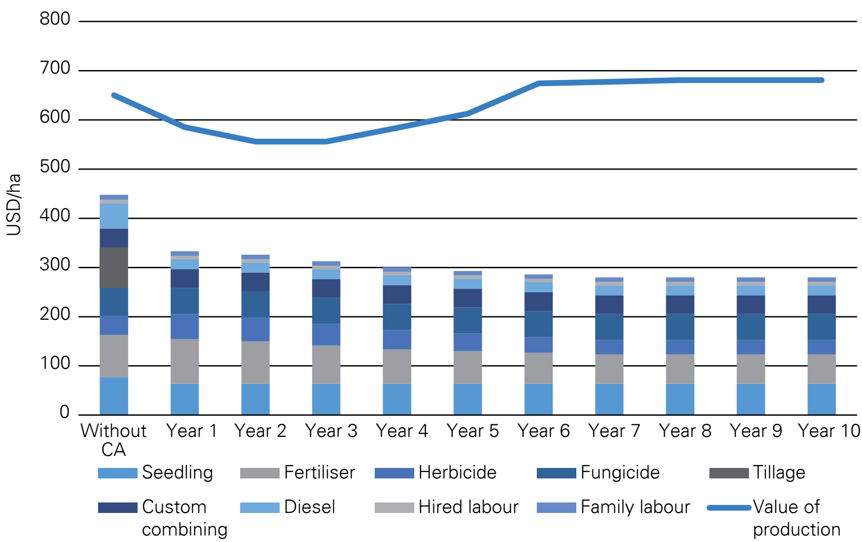
- A 10 year time period of analysis and financial prices;
- A conventional-till scenario with a 5 ha farm conducting wheat/fava bean rotations and 0.5 percent decline in yields as of year 5;
- A CA technology scenario with:
  - Initial capital cost of USD 10 000 for the direct seeder (with a 50 percent public subsidy and use by only one farmer); no change in O&M costs relative to CT.
  - Initial drop in yields by 15 percent over the first 2 years stabilising in year three as CA is adopted. Growth with final yields 5 percent above starting level. This is a particularly conservative assumption since according to most international evidence, when the system is well implemented and mastered from the start, there should be no drop in yields. In addition, according to the PICCPMV results, the introduction of CA "…guaranteed competitive yields relative to the traditional tillage-based system both in years characterised by above-average precipitation (46 percent higher yields 2012–2013) and in drought years (100 percent higher yield in 2011–2012, when farmers in tillage-based systems did not achieve any harvest)." The PICCPMV results suggest that in the Chaouia region the no-till soft wheat yields stood at 3 500 kg/ha while those of conventional systems did not surpass 2 500 kg/ha.
  - All costs change as per Table 8 with the exception of fertiliser costs, which increase in the first year but progressively decline, ending up 30 percent below the initial level and fuel use, which is assumed to decrease by 30 litre/ha peryear.

The results of this simple model are shown in Figure 17 for a 1 hectare farm. This model cannot be considered representative of Moroccan farms and a

33 Normally three categories of permanent soil cover are distinguished (30–60 percent, 60–90 percent and above 90 percent). Below 30 percent cover is not considered as CA.

complete analysis for different farm sizes, agro-ecological and socio-economic conditions would need to be conducted. In addition, the simple model above does not consider benefits in terms of more stable yields due to CA under droughts (which periodically impact Morocco's agriculture), possibly greater reduction in fertility in the conventional-till scenario with soil health degradation, as well as possible reduction in labour costs due to CA adoption. An important consideration is that no-till can also result in extra rigidity in the rotation patterns in order to ensure control over pests and this may be unappealing to some farmers (depending on market possibilities for different crops, labour availability and other considerations). It should also be noted that seed drills are not currently adapted to Moroccan soils and may require more powerful tractors, therefore increasing overall upfront investments by farmers willing to switch to CA.

Figure 17: One hectare model: Estimated evolution in value of production and cost structure from adoption of CA



Source: Authors' calculations using Boughlala et al. (2011).

The simple model suggests some interesting conclusions using financial prices (including all taxes and subsidies):

- Attaining an IRR of 12 percent (to reach the financial discount rate) would require an individual farmer to have at least 14 ha of land cultivated even with a 50 percent subsidy for the purchase of the direct seeder. This is in the upper range of existing farm sizes in Morocco. In fact, a small farmer buying the equipment by himself (without renting it) and adopting CA practices would result in negative returns to the investment.

- With the subsidy in place and assuming small farmers have on average 5 ha of land, farmers would have to buy the equipment and share its cost to achieve acceptable returns. An alternative for achieving an attractive IRR (above 12 percent) would be for an individual farmer to rent the equipment to others. Assuming an operating rental profit of USD 30 per hectare (in line with operations of renting farm machinery in Morocco) the farmer would need to use the equipment on an estimated 35 ha of other farmers' land. This is not unreasonable since with conventional seeders there is a very active rental market.
- Even without the subsidy in place (or for farmers that are not able to take advantage of it), as long as a seeder's cost is shared by at least six farmers (assuming our model's 5 ha per farmer), the IRR of adopting the technology is above 12 percent.
- If a direct seeder can be used on approximately 200 hectares, a rental business can be quite profitable. A rental operating profit of USD 30 per hectare would make investment in a direct seeder rental very profitable even without an acquisition price subsidy of 50 percent and an IRR just above 40 percent.
- Most importantly, even with the subsidy in place, depending on the number of farmers involved in the acquisition, the initial investment cost can still be high. Moreover, if farmers are not able to quickly achieve good yields (as simulated in the present model), farmers would only see a positive impact in cash flows from technology adoption in the second year. This combined with the initial investment can result in an adoption constraint depending on credit /working capital availability. It also suggests that (as discussed previously) technical assistance for correct adoption may be key to increased penetration of the technology.

In sum, it is likely to have a financial IRR above 15 percent in a normal scenario of number of hectares per direct seeder (i.e. close to what is observed today in Morocco for conventional seeders). It is therefore concluded that the technology seems to be attractive financially.

Mitigation cost

Criterion score: **

Economic considerations

While Morocco has by and large reduced interventions in the agricultural sector through privatisation and liberalisation of many subsectors (for example oilseeds), several policies still drive a wedge between the returns to CA adoption from a country perspective (economic) and the returns from an individual agent's perspective (financial). These are listed here:

- Equipment subsidies. The *Fonds de Développement Agricole* annually publishes the conditions to access equipment subsidies as an attempt to foster modernisation of the agricultural sector in Morocco. At present there is currently a 50 percent subsidy for the purchase of a direct seeder up to a maximum of MAD 90 000. In addition, smaller farmers organized in groups (*groupement*) can benefit from a 30 percent subsidy. The economic cost of the seeder is therefore double the cost to the agent as the remainder is financed by taxpayers.
- Wheat sector support and other. As part of the PMV agricultural strategy, the government continues to implement measures supporting cereal production. Measures include establishing a reference price for local wheat purchases, storage premia and subsidies for certified seeds (MAD 500 per tonne). In addition, the government intervenes directly in trade through adjustments to the common wheat tariff. As a result of all these measures, a well-organized value chain, difficulties with mechanisation of leguminous crop production and the lack of a well-established oilseeds sector, farmers may be hesitant to establish crop rotations that would help control weeds and pests. These factors can act as a deterrent to adoption.

Overall the economic returns to adoption of the technology at present in Morocco are lower than the financial ones mainly because of the value of the equipment subsidy. By making adjustments to taxes and removing the subsidy element (as it would be accounted as an economic cost), the returns from a country perspective are dependent on the efficiency of the technology deployment. According to the simple model used with economic pricing, a minimum of 20 ha per seeder is required in order to achieve an economic IRR above the social discount rate (SDR) of 8 percent. This should be possible given what is currently observed in the traditional seeders market.

Mitigation cost estimate

In estimating the mitigation cost, we have used our simple model for the net present value (NPV) of economic costs and benefits per hectare of adopting the technology (excluding the equipment subsidy and assuming an 8 percent SDR) and the potential annual GHG emissions reduction per hectare of 630 kg CO_2eq (from above). The results are extremely sensitive to the assumed level of investment cost per hectare in direct seeders. If we assume any value equal to or above USD 1 000 per hectare for the investment costs in equipment, the mitigation cost is estimated to be positive (this is equivalent to around one seeder per 20 ha of land). In sum, it depends on the efficiency of deployment of direct seeders (their capacity utilisation). At one extreme, if we assume an efficient number of direct seeders in Morocco (i.e. one for every 200 hectares), the mitigation cost would be around USD -140 per tCO_2eq. Taking an inefficient number of seeders (for example one every 15 ha) would result in a positive mitigation cost of around USD 45 per tCO_2eq. While it is difficult to estimate the mitigation cost, it is important to highlight that, while the subsidisation policy can act as an incentive to adoption, it can in certain situations also result in an inefficient amount of equipment being acquired and thereby increase the mitigation cost.

Data availability

Criterion score: **

Data on areas of different cultures and hectares under CA are available at the MAPM. Scientific data ("norms") are available in the publications of INRA and IAV, and in particular data have been collected as a result of the evaluation of the PICCPMV project. Still, most experiments are based on small farms and there is the need for more research and data on actual short- and medium-term impacts of CA in the country.

There is insufficient information on what the optimal number of direct seeders per hectare is and what the market dynamics of seeder roll out might be (especially given that direct seeders in Morocco are still at early stages of market penetration). In addition, there is no readily available information about sales of direct seeders versus conventional seeders, although data can eventually be obtained from trade statistics (since most direct seeders are imported) and local manufacturers and traders.

Efficient field machinery

Table 9: Summary of the techno-economic criteria scoring for efficient field machinery in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
***	**	*	***	***	***	***	*

Source: Authors' compilation.

In Morocco, 64 000[34] agricultural tractors are responsible for the consumption of about 576 000 m^3 of diesel every year[35], resulting in the release of approximately 1 555 KtCO$_2$eq/year. In addition, the country's current tractor fleet is estimated

34 The study AMIMA-IAV Hassan II (2014), reported that 63 000 tractors were in the country in 2013. According to national experts, the number has likely risen to 64 000.

35 This was calculated considering an average of 600 working hours/tractor/year, and 15 litres of diesel consumption/tractor/hour, based on national experts' opinions.

to meet only about two-thirds of total need. According to national research, an average of 5 600 new tractors would have to be added to the fleet every year until 2020 in order to meet growing demand generated by the PMV (MAPM, 2011). However, given recent numbers, most local experts believe that the sale of more than 4 000 additional new units every year until 2020 is not likely.

Technical assessment

Performance compared to international best practice

Criterion score: ***

Almost all agricultural machinery engines in Morocco are EURO2. EURO2 engines were introduced in 1996and are the only standard currently required for agricultural tractors in the country. Tractors equipped with EURO3 engines are also available in Morocco, but these aim to reduce air pollutants, which in fact results in a slight loss of power, and therefore in a higher fuel consumption than EURO2 engines (Pype, 2011; Talpin, 2010). For this reason, this note does not deal with the replacement of tractors, but assesses instead management and operation practices that aim to reduce fuel consumption. The practices of efficient machinery management and energy efficiency testing are in line with best international standards. This is because most of the technology and techniques are not substantially different from those available elsewhere. Still, it is worth mentioning that fuel efficient machinery (as much other equipment) is seeing constant technological improvements given regulatory and other incentives mainly in Europe and the United States.

Maturity of technical support services

Criterion score: **

The practices required to optimise field machinery energy consumption are well understood in the country by technicians, although only a limited number of farmers apply them. Technical support services for energy efficiency interventions and capacity building for farmers exist but are not widespread. The degree of technical knowledge is still at an early stage with many operators unaware of the practice.

Potential to reduce annual GHG emissions

Criterion score: ***

Based on the experience of several of its member countries, the European Parliament (2014) has set the goal of reducing fuel consumption of mobile farm machines by 10 percent; other projects have set more ambitious goals of 20 percent (Intelligent Energy Europe, 2013). Given the general low performance and poor maintenance of tractors in Morocco, empirical research suggests that testing agricultural tractors on dedicated testing benches and conducting motor tuning could increase energy efficiency and diesel fuel consumption savings of around 20–25 percent (MAPM, 2011). As a base case scenario to estimate the potential for annual GHG emissions reduction, it is further assumed that, of the tractors that are currently older than 5 years in Morocco (around 19 200 units), 30 percent (i.e. 5 760 units) undergo testing and motor tuning. In addition, average fuel consumption of 15 litres of diesel fuel per hour and around 600 hours of operation per year are assumed. The result is a total of 30 thousand tCO_2eq that could be saved annually.

However, considering that (i) 70 percent of tractors are under 5 years old and (ii) in the next 5 years the number of tractors is expected to increase by 4 000 units a year, it is clear that the number of tractors over 5 years old will gradually increase with time. If it is assumed that over the next 10 years, 30 percent of the tractors will be tested and tuned when they reach 5 years, then the average potential to reduce annual GHG emissions as a direct consequence of motor tuning will reach 58 thousand tCO_2eq/year (average for the next 10 years), or about 0.25 percent of the total emissions of the agrifood sector.

In addition to motor tuning, a number of operational measures could allow for further diesel consumption savings of up to 18 percent. These measures do not require specific or measureable investment, but are rather the result of increased awareness amongst farmers and/or training programmes provided by experts and operators. The measures and their potential savings in terms of emissions are summarised in Table 10. If these savings are achieved in 30 percent of the total fleet and added to the savings from motor tuning (taking into consideration growth in the total number of tractors over the next 10 years), the total reduction in national emissions would be almost 160 thousand tCO_2eq, or around 0.7 percent of the total national emissions of the agrifood sector.

On the other hand, if the 18 percent emission reduction factor from improved practices were applied to the entire fleet and added to the mitigation potential estimated for motor tuning in the same 10 year horizon (i.e. accounting for growth in the fleet), the technical potential to reduce annual GHG emissions would reach almost 400 thousand tCO_2eq, or 1.7 percent of the total national emissions of the agrifood sector.

Table 10: Operational measures allowing for potential diesel savings and resulting GHG emissions reduction

Item	Potential diesel savings	Resulting GHG emissions reduction in thousand tonnes of CO_2eq for the existing tractor fleet (64 000 units).
Responsible/efficient driving	8%	120
Better machinery management and working organization at field level	3%	45
Better setting and maintenance of support tools	2%	30
Optimisation of transports and refuelling of vehicles	2%	30
Choice of best timing for operations (based on soil conditions, stage of maturity and cultures, etc.)	3%	45
Total	**18%**	**270**

Source: Authors' compilation.

Market assessment

Current technology adoption rate

Criterion score: ***

As of today, few farmers pay attention to field machinery management and testing aimed at reducing fuel consumption, while only the IAV Hassan II owns fixed or mobile testing benches, which are currently used for educational and research purposes. There is also a local importer of tractors who owns a fixed testing bench for personal use.

There are, however, over 200 technical visit centres that ensure compliance of cars, trucks and buses with the regulations in force in the country through regular testing. These centres could be equipped with additional equipment and specific training programmes for agricultural machinery.

Hence, the market for the adoption of new practices and construction of testing benches for tractors is largely unexplored in Morocco and there is potential for expansion.

Trends in gap between current technology uptake and technical potential

Criterion score: ***

As mentioned above, the Moroccan tractor fleet is estimated at about 64 000 units, 70 percent of which are under 5 years old, while the number of tractors is estimated to continue to increase by 4 000 units each year in the next 5 years. This means that in a business as usual scenario, the gap between current technology uptake and technical potential will continue to increase.

Economic assessment

Financial attractiveness

Criterion score: ***

Financial costs and benefits

A simple model was used to assess the financial attractiveness of motor testing and tuning to a tractor owner. The model considers that by (i) investing in inspection and motor tuning and (ii) increasing the annual engine maintenance costs by 40 percent, the tractor owner would save 22.5 percent in fuel consumption (for consumption in a business as usual situation of 15 litres per hour and 600 work hours per year). Table 11 summarises the parameters that were used.

Table 11: Summary of costs and benefits for one tractor used for the financial analysis

	Unit	Total
Without the adoption of the technology		
Maintenance and operation costs		
Maintenance	USD/year	500
Diesel consumption	Litres/year	9 000
Diesel consumption	USD/year	9 135
Total maintenance and operation costs	USD/year	9 635
With the adoption of the technology		
Costs incurred in the year of inspection		
Inspection	USD	130
Upgrade/tuning	USD	2 000
Total costs incurred in the first year	USD	2 130
Maintenance and operation costs		
Maintenance	USD/year	700
Diesel consumption	Litres/year	6 975
Diesel consumption	USD/year	7 080
Total maintenance and operation costs	USD/year	7 780

Source: Authors' calculations based on local interviews.

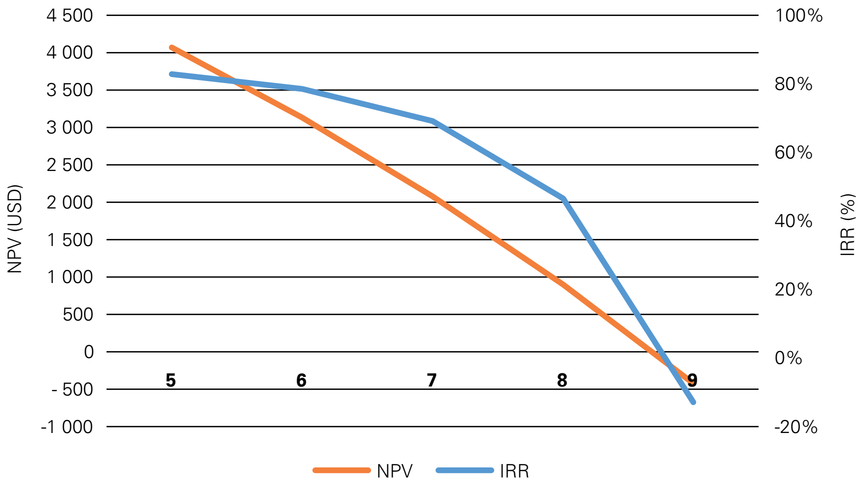
The cost of inspection was set at USD 130, which is comparable to what is charged in other countries such as France. However, this is a subsidised price since, according to the estimates, an inspection could cost on average around USD 500 per tractor, considering an operation cost of USD 280 thousand and an annualised investment cost of USD 28 thousand for an average use of 650 tractors per year.

Financial returns

An IRR of 83 percent and a NPV exceeding USD 4 000 (at a 12 percent discount rate) were estimated over a 5 year period considering that the inspection can occur at different years within the economic life of the tractor. The results are shown in Figure 18.

The data demonstrate that if the tuning of the engine is performed until the eighth year of the tractor's life – assuming that the tractor will be in operation for a total of 10 years – the diesel fuel savings compensate the investment. On the other hand, an engine tuning in the year before the tractor ends its economic life will not leave enough time for the diesel savings to compensate for the investment.

Figure 18: NPV and IRR for an inspection and engine tuning in different years of the tractor's economic life



Source: Authors' calculations.

The model is not very sensitive to the cost of the inspection: even with a cost of USD 500 it would still be financially worthwhile to tune the engine until the 8th year of the tractor's economic life.

With respect to the sensitivity of financial attractiveness to diesel savings, the analysis suggests the following: keeping all other assumptions as they are in Table 11 and considering an inspection occurring during the fifth year of the tractor's life, the break-even point corresponds to diesel savings of around 10 percent.

Mitigation cost

Criterion score: *

Economic considerations

For the economic analysis a simple model was constructed assuming that:

- the ages of 70 percent of tractors under 5 years are equally distributed, i.e. around 9 000 units of 1 to 5 years old, totalling 44 800 tractors;

- the ages of 30 percent of tractors (19 200) over 5 years are also equally distributed between 5 and 10 years;
- during the next 5 years there is an increase of 4 000 tractors per year until the number stabilises in the fifth year at 84 000 units;
- 5 testing benches in key locations of the country with the capacity to test 1 000 tractors per year each are installed in year one; each costs USD 280 thousand to equip and the same USD 280 thousand annually to maintain. The assumption therefore results in an economic cost per inspection above the financial cost assumed earlier;
- as many tractors as can be tested each year in the 5 testing benches undergo an inspection until 30 percent of all the tractors that are over 5 years old in each year are tested. This means that by year 5, more than 13 thousand tractors would have been tested and tuned;
- only tractors between 5 and 8 years old are tested;
- social and financial unit costs are the same for tractor maintenance and diesel fuel;
- the SDR is 8 percent.

The results of such a model yield an economic IRR of 100 percent and an NPV of USD 86 million.

The model breaks even for a diesel savings of around 12 percent with all other conditions remaining equal, or for only 8 percent of the tractors that are over 5 years old being tested and tuned.

Mitigation cost estimate

Considering the diesel savings estimated through the construction of the economic model and the associated GHG emissions reduction, investing in this technology appears to come at a negative mitigation cost of around USD 150 per tonne of CO_2eq in our base case scenario. Reducing the share of tractors inspected to 10 percent (versus 30 percent) would still result in a mitigation benefit of around USD 45 per tonne CO_2eq reduced. Finally, starting from our base case and reducing the diesel savings associated with testing and tuning to 10 percent would then result in a mitigation cost for the country of USD 21 per tonne of CO_2eq.

Data availability

Criterion score: *

General statistics on the number of tractors in use and their age are available at the MAPM and the Ministry of Equipment, Transportation and Logistics (*Ministère de l'Equipement, du Transport et de la Logistique* [METL]). Technical factors such as realistic achievable fuel consumption reduction, cost of efficiency measures, and information on the current uses of tractors can be partially drawn from the international literature, but an accurate assessment would require ad hoc surveys among tractor owners, which are not available.

Drip irrigation

Table 12: Summary of the techno-economic criteria scoring for drip irrigation in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
**	**	*	**	**	***	***	*

Source: Authors' compilation.

Investments in the irrigation subsector have accounted for more than 60 percent of total public investments in Moroccan agriculture from 1965 to 2000 (Ait Kadi, 2002). As a consequence, Morocco has 1.46 million hectares equipped for full control irrigation (Aquastat, 2016, data for 2011), of which 1.34 million are actually irrigated. However, most of this area – approximately 1 million ha – is under surface irrigation, whereas only about 126 thousand ha are under sprinkler irrigation, and 288 thousand under localised irrigation (Aquastat, 2016, data for 2011). According to many experts, drip irrigation is the most effective way to increase irrigation efficiency in the face of water constraints[36].

While increasing the areas under drip irrigation may reduce water use and increase yields, the impact on energy consumption is mixed because it depends on whether the energy saved from pumping less water to irrigate the same area offsets the extra energy that is needed to pressurise the system. For this reason, the technology considered in the present document is drip irrigation as an alternative to surface irrigation where the water head is above 10 m. Under these conditions and for the same crop water requirements, drip irrigation is expected to reduce GHG emissions. Naturally, drip irrigation can have many other benefits including increased farming system resilience and adaptation to climate change, especially in an agro-ecological context as the one in Morocco. Conversion from surface to drip irrigation can also decrease the use of fertiliser,

36 Drip irrigation provides the required amount of water directly to the plant by means of a rubber hose, thereby preventing losses due to evaporation, run-off or infiltration. It also improves crop quality. For instance, Balaghi et al. (2011) report performance gains for wheat with a change from surface to localised irrigation of between 20 to 90 percent in Morocco. For tree crops, the assessment resulted in yield increases up to 50 percent.

although this depends on the crops and existing practices. This would need to be analysed on a case-by-case basis after the conversion.

Technical assessment

Performance compared with international best practice

Criterion score: **

Localised irrigation can be adopted for a range of crops grown under different environments. It is technically very adaptable to the particular conditions of each location and manufacturing capacities. In Morocco, most equipment used for localised irrigation is imported, with the exception of the pipes. Systems used in the country are usually imported from Europe, and in some cases from China, and they are normally highly-performing systems in terms of energy consumption per unit of land irrigated. Hence, the adoption of high-tech systems is possible where the cost of the equipment can be justified by the increase in crop production and/or the savings in water use and where operators can be trained on its use.

A few companies have begun manufacturing drip irrigation equipment in Morocco under license. Simple emitters can be manufactured locally out of plastic or metal, though the performance may be lower than those of specialised makes. Local production of higher-performing systems will require an upgrade of the existing manufacturing processes. However, as the use of micro-irrigation increases, it is expected that a small auxiliary industry and market will develop, centred on the commercialisation of new systems as well as on equipment replacement and maintenance.

Despite their good performance in terms of drip irrigation equipment, models for integrated water management at water basin and field levels are still not commonly used in Morocco. Remote monitoring and control systems on water levels and quality and the use of sensors on soils and crops can: (i) enhance water table management, reducing pumping costs in the systems as a whole, and ensuring fair distribution of water; and (ii) increase irrigation performance, thus reducing water and energy consumption, and consequently CO_2 emissions.

Maturity of technical support services

Criterion score: **

Drip irrigation is a technology that is relatively easy to implement and can be adapted to some degree to the particular conditions of a farming system. However, its correct and efficient use requires adequate management and operation skills, even for simple systems. Lack of adequate knowledge and experience can result in emitter blockages, salinity-related problems, incorrect application of nutrients through fertigation and a lack of capacity to maintain and operate the electronic control unit and other equipment (filters, injectors, etc.). Overall, there are operators in Morocco who have the necessary skills for the operation and management of drip irrigation systems. Still, many farmers are not able to use the technology to its full potential. In addition, technical support services exist but are not widespread.

Potential to reduce annual GHG emissions

Criterion score: *

It is difficult to estimate the potential of drip irrigation to reduce annual GHG emissions. As explained above, it will depend on many variables, and in particular on the static lift, water requirements and actual irrigation efficiency. A rough estimate of the potential for this technology considering the mitigation benefits due to energy savings is presented in Table 13. This provides an indication of the scale of potential reduction and it can be concluded that, even with large variations in the values for each parameter, the emissions saved by the technology would always be quite small (around or below 1 percent of the total emissions from the agrifood sector). For instance, considering an average static lift of 30 meters for all 204 thousand hectares estimated as being under surface irrigation from underground water, the reduction in annual GHG emissions would just reach 1 percent of total agrifood emissions.

Table 13: Assumptions and method used to estimate the technical potential to reduce annual GHG emission with drip irrigation

Source	Parameter used for the estimate	Quantity	Units
a (AQUASTAT)	Area equipped for surface irrigation (2011)	1 044	thousand ha
b (AQUASTAT)	Area equipped for sprinkler irrigation (2011)	126	thousand ha
c (AQUASTAT)	Area equipped for drip irrigation (2011)	288	thousand ha
d (AQUASTAT)	Share of equipped area actually irrigated	92	%
e = (a+b+c) x d	Area equipped for irrigation actually irrigated (2011)	1 341	thousand ha
f = e-g-h	Area equipped for surface irrigation actually irrigated (2011)	927	thousand ha
g = b	Area equipped for sprinkler irrigation actually irrigated (2011)	126	thousand ha
h = c	Area equipped for drip irrigation actually irrigated (2011)	288	thousand ha
i (AQUASTAT)	Fresh surface water withdrawal (2010)	8 (78%)	10^9 m^3/year
j (AQUASTAT)	Fresh groundwater withdrawal (2010, assumed from a 10 m static lift)	2 (22%)	10^9 m^3/year
k = f x j	Area under surface irrigation served by groundwater	204	thousand ha
l (Savva & Frenken)	Energy requirement for a static lift of 30 m for surface irrigation	4 503	kWh/ha
m (Savva & Frenken)	Energy requirement for a static lift of 30 m for drip irrigation	2 866	kWh/ha
n = (l-m)/k	Energy potentially saved by changing from surface to drip irrigation	333 292 000	kWh
o = n x EF	Total emissions saved considering the grid electricity emission factor	242.9	KtCO_2eq
p (IEA)	Total emissions from the agrifood sector	23.4	MtCO_2eq
q=o/q	Share of total emissions from the agrifood sector reduced	1	%

Source: AQUASTAT; Savva and Frenken (2001); authors' calculations.

Additional possible sources of GHG emission reductions, such as decreased fertiliser use, are difficult to assess. For instance, wheat can require around 90 kg of N and 75 kg of P per hectare for a season (INRA-CRRAM, 2014), whereas tomato could require 220 kg of N, 120 kg of P_2O_5 and 190 of K_2O (MAPM, 2003). In case of a crop pattern change from wheat to tomato enabled by drip irrigation, the amounts of fertiliser could increase.

For the 204 000 ha assumed to be irrigated with groundwater and requiring a static lift above 10 m: (i) only crops with high fertiliser requirements such as tomatoes are included; (ii) there is no change in cropping patterns with conversion from surface to drip irrigation; and (iii) the emission factors for each nutrient are as reported in Table 14. As a result, the total GHG emission reduction, considering a 30 percent savings in fertiliser, would not surpass 160 000 tonnes CO_2eq/season. This means that even under optimistic assumptions, drip irrigation is not a technology with high potential to reduce GHG emissions.

Table 14: Analysis of the potential to reduce annual GHG emissions from reduced fertiliser use when converting from surface to drip irrigation

	Urea	Triple super-phosphate	Muriate of potash	Total
Amount of nutrient kg/ha (N, P_2O_5 and K_2O)	220	120	190	
Total number of converted hectares	204 000	204 000	204 000	
Emissions in fertiliser production and use (kg CO_2eq/kg nutrient)	11.19	0.56	0.43	
Total emissions for the total converted area (tCO_2eq)	502 207	13 709	16 667	532 583
Reduction of 15% in total emissions (tCO_2eq)	75 331	2 056	2 500	79 887
Reduction of 30% in total emissions (tCO_2eq)	150 662	4 113	5 000	159 775

Source: Fertilisers Europe (2011); authors' calculations.

Market assessment

Current technology adoption rate

Criterion score: **

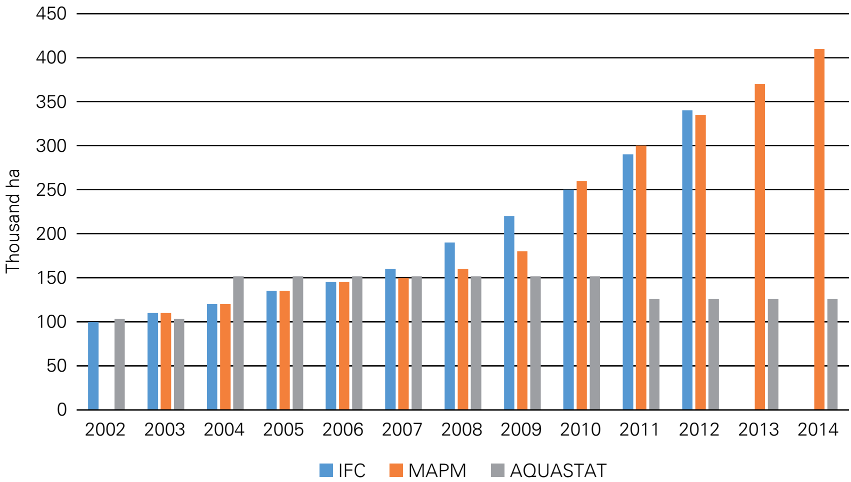
According to IFC (2015) and MAPM (2015a) estimates, drip irrigation in Morocco covers more than 300 thousand ha. AQUASTAT's latest data (2011) report that 126 thousand ha are under sprinkler irrigation. This leaves 915 thousand ha (68 percent) of the total 1.34 million ha actually irrigated in the country (AQUASTAT, data for 2011) available for conversion from surface irrigation. However, it is not certain how much of the remaining area still under surface irrigation is supplied with groundwater and could potentially be converted to drip irrigation. In addition, not all crops are suitable to be irrigated through drip systems and this would also need to be considered when assessing the market potential. A simple approach to estimating the adoption rate is as follows: according to the MAPM objectives set in 2008, around 550 000 hectares were targeted for conversion to drip irrigation by 2020 (IFC, 2014); given the evolution in surfaces converted to drip irrigation (see Figure 19) since 2008 (about 150 thousand hectares in MAPM data), around 400 thousand ha would have the potential to be converted.

Trends in gap between current technology uptake and technical potential

Criterion score: **

In Morocco, the introduction of drip irrigation in the 1990s and 2000s started informally through innovation intermediaries and labour networks (Poncet el al., 2010). Farmers who gained experience as labourers in some of the large pioneer farms adopting drip irrigation systems progressively introduced new crops to their villages with this system. Around 2005, Moroccan farmers started to use drip irrigation, particularly for sugar crops (Poncet el al., 2010). From 2002 to 2012, the share of surface under drip irrigation increased from 7 to 23 percent, according to the IFC (2015), mostly due to subsidies and overall government support. A similar trend is confirmed by the data from the MAPM (Figure 19), which report a sharp increase in the area of land equipped with drip irrigation during the same period, from about 100 thousand to 300 thousand hectares.

Figure 19: Area under drip irrigation, 2002–2014



Source: FAO AQUASTAT database; IFC 2015; MAPM 2015a.

The government is continuing to invest in this trend. The National Irrigation Water Savings Plan *(Plan National d'Économie d'Eau d'Irrigation [PNEEI])* aims at a conversion of 550 000 ha under surface and sprinkler irrigation to drip irrigation in approximately 10 years (from the time the targets were set until 2020) with partial support from subsidies under the PMV. As indicated before, this leaves a substantial amount of land still available for drip irrigation conversion. Should the targets not be completely achieved, policymakers still have policy instruments related to water pricing and use available that could give the conversion process a further boost.

The available data clearly show that the considerable gap between the current uptake of the technology and the total irrigated area in the country is gradually closing over time with the current policies. However, there is still scope for new interventions (e.g. water use monitoring and pricing) to accelerate the current speed of change.

Economic assessment

Financial attractiveness

Criterion score: ***

Financial costs and benefits

As for many technologies applied in agriculture, the financial results of drip irrigation will depend on the specific site characteristics. Depending on crops, soils, rainfall pattern, source and quality of water, or the existing irrigation system, the results yielded by the installation of one of the many technical options for shifting from surface to drip irrigation will vary. Hence, no study can be representative of the country, nor will average results from different sites have much meaning.

For the assessment of the financial attractiveness criterion, the present analysis focuses on existing data from an FAO-led project in two sectors of the Doukkala system in Morocco. It provides an example of the changes introduced by drip irrigation as a basis for discussion on the feasibility of this technology for climate change mitigation.

The project was implemented in an irrigated system comprising 96 000 ha of irrigated land with only 2 500 ha under localised irrigation and most of the system's surface under flood irrigation through gravity. The project equipped two sectors of the system with drip irrigation: sector nine with 43 ha and sector fourteen with 34 ha.

As previously mentioned, drip irrigation can only be considered a climate change mitigation technology if the water is extracted from a depth of more than 10 meters. In such cases, due to a reduction in the volume of extracted water (considering that there is no increase in irrigated area, land use intensity or cropping pattern), diesel consumption is equal or lower for drip when compared with flood irrigation[37].

The analysis is based on the following data and assumptions:

- the costs of additional pumping capacity needed to pressurise the water were taken from the Dhoukkala project;
- additional investment costs include on-farm equipment, water pipes and the system's electrification;
- additional maintenance costs are USD 170/ha (at 2016 prices)[38];

37 The analysis adopts the data from the Doukkala case study but assumes a situation of breakeven costs in fuel consumption, i.e. there are no additional energy costs considered.

38 As indicated in the Doukkala project evaluation report.

- farmers benefit from a subsidy of up to 80 percent of the investment as stipulated by the *Fonds de Développement Agricole* for individual investments (collective irrigation schemes can benefit from a subsidy of 100 percent of the investment's value);
- the investment results in yield increases and input cost reductions, thus improving gross margins as measured after the first year following adoption of the technology;
- no increase in land use intensity was considered – although it occurred in the project – as the comparison in this analysis is to be made between the same cropped areas (savings of water/diesel/emissions per hectare and unit of product).

Table 15 summarises the project investment costs, equipment economic life and subsidy policy and Figure 20 summarises the change in gross margin for the main crops[39].

Table 15: Summary of project investment costs, equipment economic life and subsidy policy

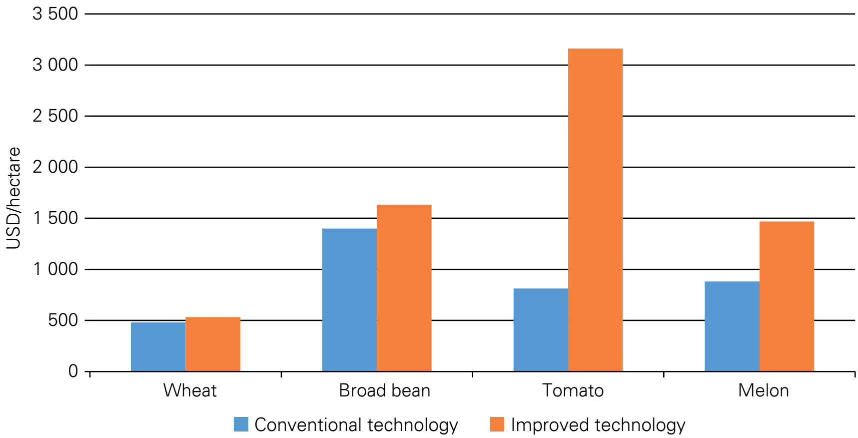
	Sector 9		Sector 14		Economic life (years)	Subsidised cost	Maximum subsidy
	USD/ha	Total USD*	USD/ha	Total USD*			
Pumping equipment	609	26 231	1 093	37 631	15	80%	USD 400/kw
Pumping stations	788	33 930	1 146	39 483	20	80%	USD 560/ha
Water pipes	922	39 716	922	31 758	30	80%	USD 960/ha
On-farm irrigation equipment	1 924	82 852	1 865	64 232	20	80%	USD 1 360/ha
Electrification	6	264	14	467	7		
Total	4 249	182 993	5 040	173 570			

Source: FAO, 2012c.

*2016 prices updated from 2009 with the World Bank Manufacturers Unit Value Index.

39 Sugar beet is an important crop in the area influenced by the project. It occupied 15 and 25 percent of the area in the two sectors before the project and 35 and 43 percent in the year immediately after. However, for this analysis, its areas were distributed amongst the remaining crops, as virtually no sugar beet is grown in areas supplied with groundwater.

Figure 20: Change in gross margin for the main crops in the two analysed sectors



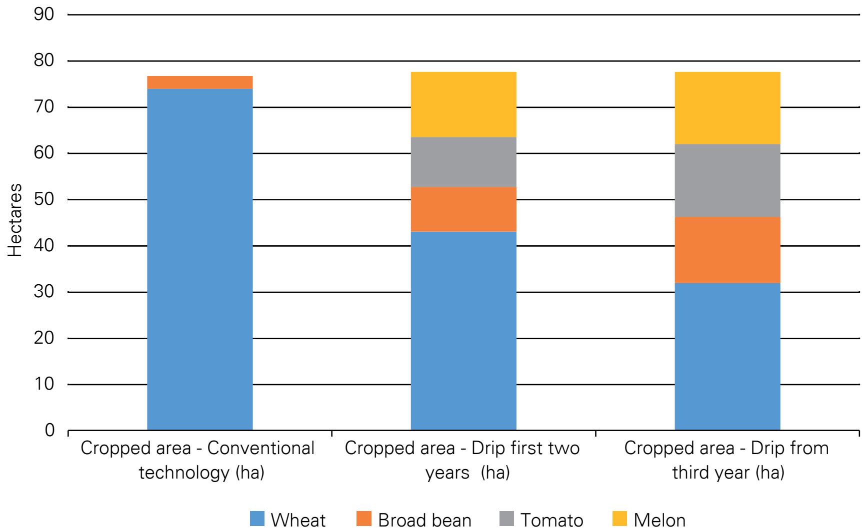
Source: FAO, 2012c.

Financial returns

Given the data described above, a simple model of the shift from surface to drip irrigation was built with the following key parameters:

- a 10 year time period of analysis and financial prices;
- a flood irrigation scenario with 74 hectares of wheat and 3 hectares of broad beans;
- a drip irrigation scenario for the first 2 years with 43 hectares of wheat, 10 of broad bean, 11 of tomato and 14 of melon. Changes in cropping patterns are shown in Figure 21;
- a drip irrigation scenario from year three onwards with 32 hectares of wheat, 14 of broad bean, 16 of tomato and 15 of melon.

Figure 21: Change in cropping pattern following technology adoption



Source: FAO, 2012c.

Note: Cropped areas were modified by the authors to match a hypothetical case without forage for which there were no data (area of forage was incorporated under wheat) or for sugar beet which is out of the scope of this study (area of sugar beet was distributed proportionally amongst the remaining crops.

No costs associated with the distribution and scheduling of water use amongst the beneficiaries were considered. The simple model that was used suggests some interesting conclusions using financial prices (i.e. including all taxes and subsidies):

- An IRR of 38 percent can be obtained even without an increase in land use intensity.
- The IRR estimate is conservative as it considers that the gross margins will remain the same as in the first year when it is natural that, as farmers adjust their practices, yields will further increase and pumping costs and input use will decrease. The project assessment report mentioned that in this first year, several farmers miscalculated the amount of fertiliser to provide through fertigation or supplied too much water to the crops.
- Despite the absence of an increase in land use intensity or an expansion in irrigated area imposed on the model by this analysis, it is expected to increase in most cases, as it has in Doukkala (which is still achieving water savings between 30 percent to 50 percent [FAO, 2012c]).

- Despite the positive financial results and the 80 percent subsidy to virtually all equipment, the cost of installation of the given example is USD 4 600/ha (USD 1 700/ha with subsidies), which can be an important barrier to adoption. In fact, Berrada (2009) reports that most areas equipped with drip irrigation in Morocco in 2008 belonged to medium or large land owners.
- Berrada (2009) mentions that many farmers are not convinced that drip irrigation can be profitable for crops such as wheat, barley and alfalfa. This is important, because in order to be financially attractive, drip irrigation may require a shift from the crops that are now dominant in surface irrigation systems according to FAO (2012c), implying an increase in water requirements. Net water requirements for one wheat crop in Morocco are estimated to be between 170 mm and 290 mm or as much as 120 mm for alfalfa, whereas for citrus, the water requirement may reach 1 200 to 1 700 mm (Berdai et al, 2005).

Mitigation cost

Criterion score: ***

Economic considerations

The economic results for the example above were obtained by subtracting the existing subsidies to equipment from the financial analysis and the use of an SDR (8 percent). However, as explained in the section on CA, while there are distortions to prices in Morocco, these were not taken into account as there are no detailed crop budgets available for the case of Doukkala that would enable the application of coefficients to unit prices of wheat and seeds. Nevertheless, the analysis performed for CA also showed little difference between economic and financial results.

With the above assumptions, the estimated IRR at social prices is 12 percent. However, a relaxation of the assumptions made in the model will easily result in an IRR above 5 percent. For instance:

- If gross margins increase by 10 percent over the ones obtained in the first year of the project, which is a reasonable assumption considering the results used are those from the first year after implementation, the IRR would be 19 percent.
- If an analysis is made for a system exclusively dedicated to growing fruits and vegetables, water savings and yield increases may be much larger and provide more satisfactory results. In fact, Berrada (2009) asserts that drip irrigation is cheaper and easier to install and manage in orchards than for non-tree crops such as alfalfa, partially because it does not require as many drip lines.

Mitigation cost estimate

The estimates of an average or indicative mitigation cost for drip irrigation is not possible because it depends on a number of variables, such as water depth and individual crops water requirements, but also on land use intensity and change in cropping patterns brought by the shift in irrigation technology. Considering drip irrigation in general terms (i.e. across all possible scenarios for adoption of the technology), the analysis seems to point to modest costs of mitigation, the main reasons being:

- GHG emissions savings are only possible in very specific situations as explained above, such as sites where water is pumped from a static lift superior to 10 m. Even in cases where these conditions (or more favourable ones) hold, the energy (and GHG emissions) savings require that there is no shift to more water demanding crops or extension of area under irrigation, which may well happen in the average type of situation when farmers switch to drip (this line of argument is further developed in Step 3).
- The financial analysis, although not representative, suggests that there is a strong incentive to expand the area under cultivation and/or the crop pattern to more water (and possibly fertiliser) demanding crops once a drip irrigation system is installed. This might still allow for water savings (the project reported savings from 30 to 50 percent even with increases in land use intensity and changes in cropping pattern) but, depending on the depth of the water table, these might not be sufficient to reduce energy consumption from pumping.

Even considering that drip irrigation can increase land productivity and that these may translate also to improvements in energy productivity (even if not in absolute savings), promoting drip irrigation as a climate mitigation technology is debatable and requires a cautious use of different policy instruments. Most sites in Morocco suffer from water scarcity, and as in the case of Doukkala, crops are being irrigated with suboptimal quantities of water (FAO, 2012c): 400 million m^3 of water for an actual requirement of 859 million m^3 for the 96 thousand hectares. Hence, on-site GHG emission savings may be difficult to obtain, as similar amounts of water may continue to be abstracted following the shift from flood to drip irrigation (to provide crops with an optimal quantity of water, increase cropped area and land use intensity and maximise the returns on investment). Imposing restrictions on water use and cropped area expansion for farmers could be an option but may also lead to lower adoption. Of course, in the case that no such restrictions are imposed on farmers and water savings are used in new areas or in an extra growing season, global GHG emission reductions may still occur if the increase in local production displaces food produced and transported in a less energy-efficient way – but this is not easy to assess or quantify.

Data availability

Criterion score: *

Numbers on the investments and areas associated with drip irrigation are available from official sources. However, defining the situations in which drip irrigation can be considered a climate change mitigation technology is not an easy task. Although it was assumed that drip irrigation could be considered a climate change mitigation technology under certain conditions, it is not known how much water is extracted in the country at each static lift interval, nor how much consumption could be reduced through a shift from flood to drip irrigation. Hence, a precise estimate of the potential to reduce GHG emissions is not possible with the available information.

Solar/wind-powered water pumping

Table 16: Summary of the techno-economic criteria scoring for solar/wind-powered water pumping in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
***	**	**	***	**	***	***	*

Source: Authors' compilation.

In the case of pressure irrigation, wind or PV systems need to continuously power the irrigation system and, in order to do this, they can rely on a battery, the national grid or a fossil fuel backup. Alternatively, water can be stored in a tank or reservoir to be used in low pressure or gravity irrigation systems.

Depending on the water needs and water head, the pump's size can vary. Power systems are typically between 1 to 4 kWp. The area of installed PV panels will change based on pump capacity and can be small and freestanding on a tower (see Figure 22) or installed on an area of land[40]. Wind turbine-powered electric pumps for irrigation usually consist of a wind turbine mounted on a tower with rotor sizes varying in size[41].

40 Lorentz (2013) provides an example from Oujda, Morocco, of a system comprising 60 m^2 of crystalline solar panels with 10kWp and the ability to pump 120 m^3/day.

41 For example, Zein (2014) provides examples of rotor diameters from 4 to 7.4 meters and capacities to pump water volumes ranging from 11 to 89 m^3 per day for wind speeds between 3.7 and 4.6 m/s.

As mentioned above, the climate technology assessed here focuses on solar and wind applications without energy storage; however, the economics associated with off-grid energy storage pumping are also provided. Moreover, the option of switching between LPG and PV is provided for information, since butane use for pumping is currently illegal in Morocco.

Figure 22: Solar pump

Source: Maroc Solaire.

Technical assessment

Performance compared with international best practice

Criterion score: *

Solar and wind pumping equipment in Morocco is imported from abroad, mostly from Europe. As a result, the most efficient technology available on the international market is commonly available and used in the country.

Maturity of technical support services

Criterion score: **

Solar and wind-powered pumps are mature technologies and support services for their installation and maintenance are distributed widely in the country. They are easy to install, operate and maintain. However, there is progress to be made in ensuring that small-scale farmers can have access to training on the O&M of the systems (FAO-GIZ, 2015).

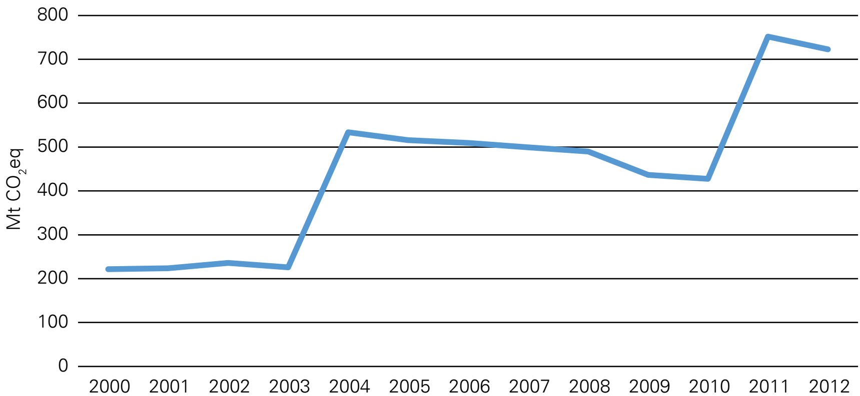
Potential to reduce annual GHG emissions

Criterion score: **

Currently, the country has around 165 000 pumps used for irrigation (IFC, 2015) and the total energy use in irrigation in 2012 (for sprinkler and localised irrigation) was estimated at around 1 000 GWh (FAOSTAT, 2016), corresponding to more than 0.7 Mt CO_2eq per year (Figure 23).

Given the climatic conditions of Morocco, it is technically possible to reduce GHG emissions from power irrigation to zero by using solar or wind power[42]. Therefore, the potential GHG emission reduction is around 722 kt CO_2eq/year, which represents 12 percent of energy from agricultural emissions or 3 percent of the agrifood sector's emissions.

Figure 23: Emissions from energy for power irrigation in Morocco, 2000–2012



Source: FAOSTAT, 2015.

42 The climate technology considered here focuses on water pumping without energy storage. Therefore, pumping can occur just during certain periods during the day (with the water reservoir acting as a buffer) unless the system is on-grid and the electricity grid is always available.

Market assessment

Current technology adoption rate

Criterion score: ***

According to the IFC, the current market penetration of PV-powered pumps is quite marginal and wind-powered pumps negligible. The IFC (2015) estimates the country has around 165 000 pumps, and fewer than 10 percent operate with solar energy. These figures reveal a large potential for further penetration, as the government is to execute a new subsidy policy for solar and wind-powered pumps and investments may be on hold. Subsidies to LPG may also be holding back the substitution of fuel-powered pumps by solar ones (further discussed later).

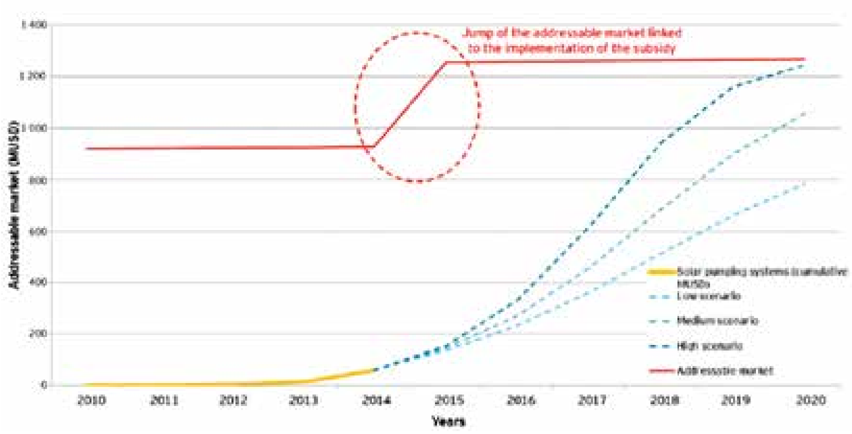
Trends in gap between current technology uptake and technical potential

Criterion score: ***

Solar and wind-powered pumps have seen increased adoption in the last few years. This trend may increase further with a foreseen USD 300 million programme for solar pumping to be implemented by CAM in the context of the PMV. The programme is targeting the substitution of 100 000 pumps by 2020. The subsidy plan will provide up to a 50 percent subsidy on solar pumping systems, along with drip irrigation installation. The possible implications of this subsidy in the adoption of the technology in the next few years is discussed below.

IFC estimates that more than 60 percent of the total number of water pumps could be replaced by 2020. The value of the Moroccan solar pumping market by 2020 is estimated to be between USD 800 million and USD 1.3 billion (Figure 24).

Figure 24: Estimated market potential for solar pumping in Morocco, 2010–2020



Source: IFC, 2015.

These efforts are further supported by priorities from the third National Communication document, which outlines additional plans to expand the solar pump programme. The programme now aims to install 30 000 PV pumping systems between 2015 and 2025 and provide grants to farmers on small-sized farms for all types of solar pumping systems[43]. Funding covering 50 percent of investment costs will be made available to projects with a ceiling of MAD 75 000, and total government investment is estimated to reach EUR 90 million for 2015-2025.

Economic assessment

Financial attractiveness

Criterion score: ***

Financial costs and benefits

The financial attractiveness of a solar irrigation system is a function of crops and location, i.e. water requirements and availability and sun or wind conditions, as shown for example in the case studies analysed by Kelley (2010) and Odeh et al. (2006). These analyses look at two Moroccan examples to discuss the feasibility of such systems, though they do not aim to be representative

43 Farms with 5 ha and below are considered small-scale in Morocco. These farmers were targeted in this project for a number of reasons, notably because they are major consumers of butane, and because they are generally most disadvantaged in terms of access to credit. This programme is expected to be extended to include medium farms (up to 10 ha) as well (IFC, 2014). For more information, see Missaoui, 2014.

of the potential for the use of RE sources to pump water in Morocco. One of the examples is a 10 kWp system set up to irrigate 6 ha of olive trees in Oujda pumping 120 m^3 per day; the second example analyses the installation of a 1.35 kWp system pumping for irrigation, livestock and domestic use.

For the 10 KWp system, the analysis is based on a case study from a PV-powered pump provider (Lorentz, 2013). The data from the case study were validated and adapted by national experts. Main system characteristics and assumptions are as follows:

- the system comprises two pumps, one equipped with a 4 kW motor to draw water from a 40 metre deep bore well and pump it into a 3 000 m^3 reservoir, and a second with a 1.4 kW motor to pump water from the reservoir for the irrigation of 6 ha (see Figure 25);
- both pumps can pull 120 m^3 of water per day, i.e. a maximum yearly amount of water of 43 800 m^3;
- the system is equipped with 40 PV modules sized 1667×994×45 mm (60 cells, sized 156×156 mm) with a power of 10kWp;
- installation costs total USD 16 800 and maintenance costs, adapted from the estimates in Kelley et al (2010), are USD 1 000.

This system's costs are compared with the costs for the same system with pumps powered by electricity, diesel and LPG (even though butane use for water pumping is illegal, it is reportedly still practiced in Morocco). O&M costs are given by Lorentz (2013) and include diesel or butane transportation. Fuel costs are based on the national prices used throughout this document, and include subsidised butane, considering its possible illicit use for domestic purposes in irrigation[44]. Table 17 summarises this information.

44 The government estimates that as much as 100 000 ha may currently be irrigated with LPG-powered pumps (MDCE, 2016).

Table 17: Comparative summary of electric, diesel, LPG and PV (10 kWp) pumps costs for an energy yield of 100 kWh/day

Energy Source	Electricity	Diesel	LPG (butane)	PV
Energy yield (kWh/day)	100	100	100	100
Cost per unit of fuel (USD/ kWh)	0.12	0.10	0.02	0
Fuel cost per day (USD/day)	11.8	10.4	2.5	~0
Fuel cost per year (USD/yr)	4 294	3 811	907	~0
Operations and maintenance (USD)	600	1 200	1 000	1 000
Initial capital cost (USD)	2 400	2 400	2 400	16 800

Source: Lorentz (2013), and authors' calculations based on expert consultation.

Note: O&M costs are indicative as they largely depend on the existence of qualified maintenance staff based in the local vicinity (Senol, 2012).

Figure 25: Solar water pumping for irrigation in Oujda, Morocco

Source: Lorentz, 2013.

For the 1 kWp system, the analysis is based on a system with a PV array of 15 monocrystalline modules totalling 1.35 kWp, and one pump equipped with a 0.3 kW motor with the capacity to draw 10 m^3 water per day (5 hours of peak) from a 20 metre deep bore well. The pump can be installed either:

- *With a battery to pump water during cloudy weather*: Installation costs are estimated according to local suppliers, totalling USD 7 000 for a full installation of PV-generator, inverter, pump and batteries. It is assumed that pre-existing electrical pumps do not need replacement and the cost of installation would therefore be deducted from the value of the pump, totalling USD 5 500.
- *Without a battery, pumping to a previously existing reservoir*: Installation costs are also estimated according to local suppliers, totalling USD 1 500 for a PV generator and inverter (to apply on an existing electric pump) or USD 3 000 for a PV generator, an inverter and a pump in the case of a replacement of a diesel or LPG pump.

As for the previous system, PV-powered pumping costs are compared with the costs for the same system with pumps powered by electricity, diesel and LPG (at subsidised variable price). Table 18 summarises this information.

Table 18: Comparative summary of electric, diesel, LPG and PV (1 kWp) pumps costs for an energy yield of 1 700 kWh per year

Energy Source	Electricity	Diesel	LPG (butane)	PV (with battery)	PV (without battery)
Energy yield (kWh/year)	1 700	1 700	1 700	1 700	1 700
Energy cost (USD/kWh)	0.29	0.26	0.06	0	0
Fuel cost per year (USD/year)	500	444	106	0	0
Operations and maintenance (USD)	84	167	139	84	84
Initial capital cost (USD)	0	500	500	7 000/5 500	3 000/1 500

Source: Energy yields estimated using the Photovoltaic Geographical Information System; energy costs from current energy prices and standard energy content; capital costs from national experts.

Note: O&M costs are indicative as they largely depend on the existence of qualified maintenance staff based in the local vicinity (Senol, 2012) and the proximity of fuel suppliers.

Financial returns

Given the data described above and additional information collected locally, a simple model of substituting a conventional pump with a PV pump in Morocco was built with the following key parameters:

- a 10 year time period of analysis, financial prices and a financial discount rate of 12 percent;
- estimated PV system lifetime of 15 years; at the end of the analysis period there is a small salvage value in the case of PV investment;
- three scenarios for the installation of new pumps and generators for both examples: main grid electric pumps (electricity) vs. PV, diesel vs. PV and LPG vs. only PV;
- two additional scenarios for the 1.35 kWh generator example: (i) installation of a complete system comprising battery and associated electrical components such as fuses, switches, and conductors and (ii) installation of a system without batteries (PV modules, inverter and, in case of diesel and LPG systems, a new pump);
- results are presented both without subsidies for solar equipment and installation (current situation) and with the foreseen 50 percent subsidy to RE-powered pumps, which will become the new financial price. In addition, as discussed above, butane subsidies are included in the costs of operating LPG powered pumps (even if illegal).

The results are summarised in Table 19.

Table 19: Cost-benefit analysis of the substitution of electric, diesel and LPG pumps with PV pumps at financial prices

Pumping system conversion	Subsidy	NPV (thousand USD)	IRR	Payback years (not discounted)
10 kWp - 120 m³/day				
From electricity to PV	without	9.0	26%	4
	with	15.7	66%	2
From diesel to PV	without	9.6	27%	4
	with	16.3	68%	1
From LPG to PV	without	-6.0	1%	16
	with	0.6	14%	7
1 kWp - 28.5 m³/day				
From electricity to PV (with battery)	without	-1.7	4%	11
	with	0.4	15%	5
From electricity to PV (just PV modules and inverter)	without	1.2	31%	3
	with	1.9	66%	1
From diesel to PV (with battery)	without	-2.3	3%	12
	with	0.4	15%	6
From diesel to PV (without battery)	without	0.6	18%	5
	with	1.9	54%	2
From LPG to PV (with battery)	without	-4.2	-5%	40
	with	-1.4	0%	19
From LPG to PV (without battery)	without	-1.3	-5%	16
	with	0.05	13%	6
Average results	**without**	**0.8**	**15%**	**6**
	with	**4.0**	**38%**	**3**

Source: Authors' calculations based on Tables 17 and 18.

The simple models that were used are not representative of any region or set of situations in Morocco and are fairly sensitive to changes in installation and operation costs, and should thus be interpreted with caution. Nevertheless, the simple model suggests some interesting conclusions using financial prices (i.e. including all taxes and the subsidy to butane gas):

- There is little or no incentive to change to solar energy-powered pumps without a subsidy and/or as long as subsidised butane gas is widely used to power water pumps.
- For larger systems, such as that of the first example above, conversion from electrical and diesel systems can be a good option as demonstrated by existing experiences; this seems to be the case even in the absence of subsidies.
- The financial attractiveness of switching to PV technology for smaller systems equipped with diesel or electricity-powered pumps is mixed. In cases where batteries do not have to be installed, solar pumps can be marginally attractive, provided the use of subsidised butane gas is not an alternative. However, the results indicate that solar pumps without batteries need reservoirs in which water can be stored for energy use (e.g. through gravity irrigation). Systems with batteries will only be feasible for the farmers if the equipment and installation costs are subsidised.
- If the subsidy to the installation of solar-powered pumping is put in place and the subsidy to butane gas is removed, all the characterised cases would be financially feasible.

The analysis does not consider mixed systems, e.g. a solar-powered pump connected to the electricity grid for back-up on cloudy days, as this can be an intermediate solution between those presented.

In general, it seems that, for larger applications where economies of scale contribute to reduced installation and equipment costs per cubic meter of pumped water with solar energy, the conversion is financially feasible. In cases where the system needs to be installed to pump smaller quantities of water, its use for pressurised irrigation may not be financially feasible.

The analysis signals that in a context in which drip (pressurised) irrigation is to be promoted and farm sizes are often small, solar pumping may not be attractive without significant subsidisation. It may also not be financially attractive to switch to PV in systems when pumps are operated only for very limited periods of time during the year. Systems operated only for limited periods result in a lower share of variable costs as a percentage of total discounted costs (over a 10 year horizon) when compared to systems operated throughout the year (such as those including a reservoir). Higher costs associated with refuelling under conventional technologies (due to distance from fuel stations, etc.) would also make the PV alternative more financially attractive.

No financial analysis was conducted for wind-powered pumping as the results are even more dependent on local conditions than PV. However, the investment costs of a wind pump irrigation system (tower, turbine, wiring for electrical systems and pump) can add up to about USD 17 000 for 10 kWp nominal wind power (Zein, 2014) and therefore do not differ much from the first example provided above for PV. Off-grid wind-powered systems, however, require more expensive storage capacity than PV, which means both small and medium applications are less attractive. In any case, investors in Morocco seem to have a preference for solar-powered pumping and the market for wind-powered pumping seems to be almost absent. In fact, small wind turbines are much less cost-effective than large ones, while PV is much more scalable.

Mitigation cost

Criterion score: *

Economic considerations

Depending on the characteristics of the irrigation system (location, surface covered, water source, etc.), the water and energy requirements will vary, hence so will total related GHG emissions produced by conventional pumps. A cost-benefit analysis was conducted for the previous examples at economic prices: unsubsidised butane gas, unsubsidised equipment and an SDR of 8 percent for a period of 10 years. The analysis, however, does not consider other possible adjustments to financial prices, including, for example, subsidy implementation costs.

The results are summarised in Table 20. The relative results between the different models do not differ much from the financial ones, except for previously LPG-powered pumps. Without subsidies to LPG, changing from an LPG-powered pump to larger PV systems and small PV pump systems without a battery comes at a gain.

Mitigation cost estimate

The analysis finds a mitigation cost range for solar pumping without energy storage roughly between USD -380 and USD 50 per CO_2eq. This suggests that solar-powered systems with larger energy demand are interesting from an economic point of view, especially if they substitute grid electricity or diesel-powered pumps (larger NPVs). The smaller systems under analysis are only interesting from an economic point of view if they substitute systems that consist of pumps used for gravity irrigation (or human and livestock consumption) with a reservoir for water storage. All of the examples of small pumps equipped with batteries show positive mitigation costs.

Table 20: Economic analysis and GHG emission reduction mitigation costs of the substitution of electric, diesel and LPG pumps with PV pumps

Pumping system conversion	NPV (thousand USD)	Mitigation (tCO_2eq/year)	Mitigation cost (USD/tCO_2eq/yr)
120 m^3/day			
From electricity to PV	14.0	27	-53
From diesel to PV	14.7	10	-151
From LPG to PV	7.4	8	-89
10 m^3/day			
From electricity to PV (with battery)	-1.0	0.5	216
From electricity to PV (just PV modules and inverter)	1.7	0.5	-377
From diesel to PV (with battery)	-1.6	0.5	348
From diesel to PV (without battery)	1.1	0.5	-246
From LPG to PV (with battery)	-2.2	0.4	579
From LPG to PV (without battery)	0.9	0.4	-229
Average	**2.6**	**5**	**-53**

Source: Authors' calculations.

Note: Average NPV uses a simple average cash flow of all modelled pumps; mitigation: average mitigations of modelled pumps; mitigation cost = average NPV x total pumps to be installed in the country ÷ years of analysis ÷ total GHG emissions potential (722 $ktCO_2eq$/year).

Given the diversity of pump sizes, the flexibility in number and the size of PV modules to be installed as well as the variation of local water tables, crops and climatic conditions, it is not possible in such a rapid assessment to arrive at a general conclusion about the feasibility of solar (or wind) pumping for the country. What seems to be clear is that with the current technology level, installation costs and energy prices, the country's technical potential for GHG emission reduction through solar and wind pumping cannot be achieved without incurring mitigation costs in a number of cases.

Finally, in the last few years, international equipment costs for RE-powered irrigation systems have come down considerably, and it is possible that as the technology becomes more common and services more widespread throughout the country, installation and maintenance costs will decline, resulting in a more favourable environment for the substitution of electric and diesel-powered systems (including those with energy storage).

Data availability

Criterion score: *

Data on solar and wind pumps can be found from scattered reports and the following agencies or institutes in Morocco: *Institut de Recherche en Énergie Solaire et Énergies Nouvelles* (Institute of Research for Solar and Renewable Energy [IRESEN]), Moroccan Agency for Solar Energy (MASEN), *Programme Pilote d'Électrification Rurale* (Rural Electrification Pilot Programme [PPER]), and *Société d'Investissements Énergétiques* (Society of Energy Investments [SIE]). Hence, despite the existing interest in RE and its potential to substitute conventional sources of energy, data on solar and wind-powered water pumping is still dispersed and retrieving it to make use of coherent data sets is not an easy task. Additionally, the diversity of solutions and locations for solar PV and wind generator applications makes data monitoring of installed capacity, actual production and cost estimates rather difficult.

Grazing management

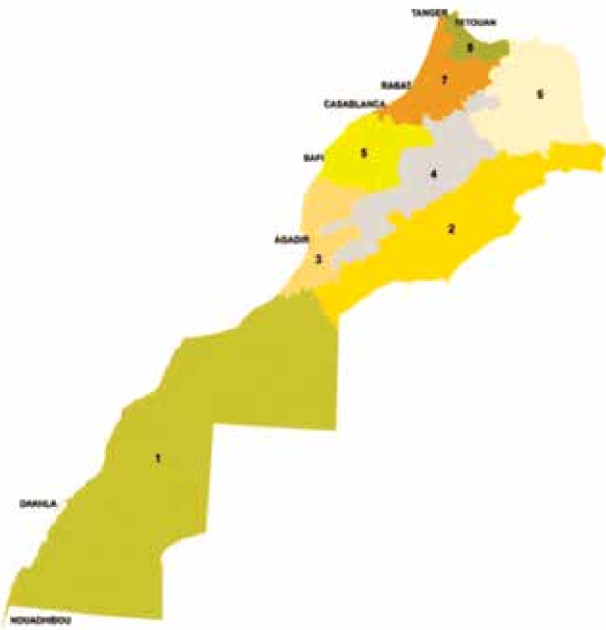
Table 21: Summary of the techno-economic criteria scoring for grazing management in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
***	**	**	***	***	*	*	*

Source: Authors' compilation.

This report assesses practices that have been tested in Morocco, such as those promoted through projects related to the Moroccan livestock and pasture development strategy financed by the International Fund for Agricultural Development (IFAD) (IFAD, 2002b), located in the *Oriental* and *Guelmim es Semara* regions of the country. These projects introduced climate-friendly practices such as improved vegetation, soil cultivation, shrubs, rotational grazing, fencing, establishment of grazing bans and the installation of shelters on a land area used to feed grazing livestock (FAO, 2006). Interventions aiming at promoting similar practices at a larger scale have been more recently programmed in the National Action Programme Against Desertification 2012–2022 (*Programme d'Action National de Lutte Contre la Désertification* [PANLCD]). The PANLCD divides the country into eight zones with different levels of soil erosion and pressure on rangelands (soil degradation) and vulnerability to desertification. Of these eight zones, the PANLCD considers that zones 3, 4, 5, and 6 have potential for interventions on grazing management improvement and identifies 10 year targets for rangeland recovery in each of them. Figure 26 depicts the eight zones and Table 22 provides a short description with the total area and the area targeted for improved grazeland management for each one.

Figure 26: Soil vulnerability to desertification and degradations zones in Morocco



Source: Haut Commissariat aux Eaux et Fôrets et la Lutte Contre la Désertification (2013); PANLCD.

Table 22: Description, total area and targeted area for improved grazeland management for each zone

Zones description	Total area (1 000 ha)	Area targeted for grazing management (1 000 ha)
1. Saharan zone – characterised by strong wind erosion where PANLCD interventions are centred around the installation of green belts around towns	32 200	0
2. Pre-Saharan zone – suffers from strong water erosion and to a lesser extent wind erosion in around 13% of its area; the PANLCD programmed interventions focus on water and soil conservation	11 000	0
3. Argan Zone – threatened by strong or excessive pressure over rangelands in 67% of its area; changes in herding practices and the recovery of the Argan forest are seen as priorities in the PANLCD	3 400	576
4. North High Atlas mountains – vulnerable to desertification and soil degradation due to excessive pressure over rangelands and water erosion; priority interventions are related to water and soil conservation and recovery of forest cover	6 700	1 365
5. Plains and plateaus north of the Atlas – threatened in almost all of their area by strong or excessive pressure over rangelands; change in herding practices is a priority for the PANLCD	3 900	981
6. Plains and plateaus of Eastern Morocco – vulnerable to desertification mostly due to excessive pressure over pastureland; requires an improvement in soil and water conservation linked to improved herding practices	7 000	1 306
7. Plaines and plateaus of the Gharb region – less vulnerable to degradation and desertification than the remaining zones; the main concern for this zone is flood containment	3 700	0
8. Agricultural plains of Prerif and Rif mountains – suffer mostly from water erosion and investment; PAMLCD interventions are related to soil and water conservation and watershed management	1 100	0
Total area	**69 000**	**4 227**

Source: Authors' compilation.

Improved grazing practices can be used for livestock completely or partially fed on grazing. With regard to cattle, the use of Morocco's natural vegetation for feeding can in some cases contribute to the extreme degradation of pastureland. As a result, farmers are becoming reluctant to have cattle in natural pastures, particularly in the alfa steppe in the Eastern Highlands, as they do not see it as profitable or sustainable. Given the apparent constraints to sustainable use of natural rangelands for cattle and the cattle-related emissions mentioned in the "livestock dairy breeds on improved diets" section, this climate practice only considers the application of improved grazing management practices for the country's population of small ruminants. The assessment assumes the FAO estimate (2004) that over 70 percent of the small ruminants in the country can be affected by improved grazing land management. Consequently, of the estimated 19 million sheep and 5.6 million goats in the country in 2012 (FAOSTAT), a total of 17 200 000 heads (70 percent) will be considered in the analysis.

Technical assessment

Performance compared with international best practice

Criterion score: ***

As mentioned before, not many initiatives on the improvement of grazing management exist in Morocco. The best known and studied are the IFAD financed projects, which have reported that 46 percent of the 44 established pastoral cooperatives survived, and about a dozen achieved results from grazing management comparable with international best practices. Pasture dry matter increased from 150 to 800 kg/ha (although only two to threefold increases are usually expected as reported by local experts), mortality rate declined from 6 percent to 2 percent (low by international standards), and average annual gross margins of grazing livestock were reported to increase by 10 percent[45]. There are best practices of grazing management being implemented in Morocco, although on a limited scale.

Maturity of technical support services

Criterion score: **

There is knowledge and experience in the country on the improvement of grazing practices and there are projects under implementation aiming at the partial implementation of the PANLCD by the MAPM of Morocco. However, improved grazing practices with the particular objective of reducing GHG emissions (while improving productivity in the medium/long-term) have not been implemented on a large scale in the country and the existing knowledge and experience is not widespread amongst technicians and herders.

45 Personal communication with Prof. Araba, local livestock expert.

Potential to reduce annual GHG emissions

Criterion score: **

The main possible sources of impact on annual GHG emissions from improved grazing management in Morocco are carbon sequestration from the restoration of degraded pastures and the reduction in enteric fermentation emissions caused by rotational grazing. The estimate presented by Smith et al. (2007) for the reduction in GHG emissions from enteric fermentation due to improved feeding practices is 1 percent per small or large ruminant. Applying this factor to the total enteric fermentation emissions from 17.2 million sheep and goats – 2.6 million tonnes CO_2eq (FAOSTAT, data for 2012) – the potential to reduce emissions from enteric fermentation is 18 thousand tonnes of CO_2eq, or 0.1 percent of agrifood sector emissions.

In addition, considering the PANLCD target for rangelands recovery of 4.23 million hectares and applying IPCC Tier 1 factors as computed by the software Ex-Act (version 7) for warm temperate dry climate, Africa, high activity clay soils, implementation phase of 10 years, capitalisation phase of 10 years, and duration of accounting of 20 years, the total potential for carbon sequestration is 1.1 million tonnes of CO_2eq.

The estimates of reduced GHG emissions from enteric fermentation and carbon sequestration through rangeland recovery together add to 1.12 million tonnes of CO_2eq, or 5 percent of the total annual agrifood emissions. Table 23 summarises the data that used for the estimates.

Table 23: Potential to mitigate emissions by rotational grazing in Morocco

Potential for emissions reduction from enteric fermentation	
Number of small ruminants heads (thousand)	17 200
Total enteric fermentation emissions (thousand tCO_2eq/year)	1 809
Emissions reduction from enteric fermentation due to improved practices of rotational grazing	1%
Total emissions reduction from enteric fermentation (thousand tCO_2eq/year)	18
Potential for emissions reduction from the restoration of degraded pastures	
Recovered degraded graze land over ten years (thousand hectares)	4 227
Total carbon sequestration over 20 years (thousand tCO_2eq/year)	1 100

Source: Authors' calculation based on FAOSTAT, 2015 and Ex-Act version 7.

Although conservative, the estimates on the potential for carbon sequestration must be interpreted with caution as they were based on the assumption that the target area: (i) is moderately degraded; (ii) would continue to be moderately degraded without any intervention; and (iii) would become non-degraded with the programmed intervention. Changes in these parameters will significantly alter the results. For instance, an intervention leading to improved pastures without input management – other factors remaining constant – would bring carbon sequestration to 4.2 million tonnes of CO_2eq per year over 20 years, i.e. 18 percent of the total annual emissions of the agrifood sector.

Market assessment

Current technology adoption rate

Criterion score: ***

Thus far, changes in grazing management practices have mostly been limited to the pasture management projects launched in the past decade by the Moroccan government jointly with IFAD (2002a). The estimate is that the improvement of grazing patterns reached just over 80 000 livestock units (LUs) (approximately 700 000 heads, mostly sheep). Assuming that all 46 percent of the cooperatives that participated in the IFAD project that are still active, practice at least part of the improvements in grazing management introduced by the project, and have equal distribution of animals amongst the cooperatives, the number of small ruminants under improved grazing management in the country is 80 000 x 0.46 = 36 800 LU. Hence the share of small ruminants under improved grazing management vis-à-vis the potential population (17 225 000 LU) is around 2 percent. Even considering that other producers have adopted improved grazing practices, overall the available information suggests that there is a major gap between the current adoption rate and its technical potential.

Trends in gap between current technology uptake and technical potential

Criterion score: ***

Trends in adoption have been slow and are apparently confined to specific projects that affected just over 400 000 hectares of land in the case of the IFAD project. At the moment, there are new initiatives aiming at improving grazing practices in the country. However, given the large area of rangelands, the gap is not expected to significantly reduce in the short to medium-term.

Economic assessment

Financial attractiveness

Criterion score: **

Financial costs and benefits

As previously mentioned, there is a large diversity of rangeland types and pasture conditions in the country and there has been limited investment in the improvement of grazing land. As such, the analysis presented here does not aim to be an accurate estimate of the potential returns from improved grazing management in Morocco, but rather seeks to provide elements for discussion. A simple model was constructed considering the overall implementation targets and interventions of the PANLDC and the costs and benefits more recently estimated for a project under implementation in *Souss Massa Drâa* and *Guelmin Es-Semara*. Main interventions consist of (i) flora improvement (sown pasture and set aside), (ii) edible shrub plantation and (iii) natural pasture regeneration (fencing-off). Herders receive a compensatory payment in the first year for losses in access to land. The distribution and values of the investment per year at 2016 prices is presented in Table 24.

The project in *Souss Massa Drâa* and *Guelmin Es-Semara* also invests in the organization of farmers into cooperatives and the development of a livestock product value chain as these investments contribute directly to the sustainability of pasture improvement by organizing and sensitising herders and providing an incentive for the adoption of livestock breeding systems based on a smaller number of more productive animals. However, this analysis only includes direct investments in rangeland improvement that are aligned with the interventions proposed in the PANLCD, as the benefits of additional investments cannot be solely attributed to the changes in grazing management practices.

Table 24: Summary of the components, intervention areas and investment costs

Zone 3 (Zone de lárganier) - Sustainable rangeland management	Area (ha)	Cost (MAD/ha)
Compensatory payment to herders	287 852	500
Flora improvement - (Set aside + soil preparation + sowing)	172 712	2 500
Edible shrub plantation + irrigation	86 358	4 500
Set aside	28 786	1 500
Total area (ha in 10 years)	575 708	
Total cost (million MAD in 10 years)		1 007.5
Zone 4 (Chaîne atlasique versant Nord) - Sustainable rangeland management	**Area (ha)**	**Cost (MAD/ha)**
Compensatory payment to herders	682 346	500
Flora improvement - (Set aside + soil preparation + sowing)	409 406	2 500
Edible shrub plantation + irrigation	204 702	4 500
Set aside	68 234	1 500
Total area (ha in 10 years)	1 364 688	
Total cost (million MAD in 10 years)		2 388.2
Zone 5 (Plaine et plateaux nord atlasiques) - Sustainable rangeland management	**Area (ha)**	**Cost (MAD/ha)**
Compensatory payment to herders	490 252	500
Flora improvement - (Set aside + soil preparation + sowing)	294 152	2 500
Edible shrub plantation + irrigation	147 078	4 500
Set aside	49 026	1 500
Total area (ha in 10 years)	980 508	
Total cost (million MAD in 10 years)		1 715.9
Zone 6 (Plaine et plateaux de l'oriental) - Sustainable rangeland management	**Area (ha)**	**Cost (MAD/ha)**
Compensatory payment to herders	653 238	500
Flora improvement - (Set aside + soil preparation + sowing)	391 940	2 500
Edible shrub plantation + irrigation	195 972	4 500
Set aside	65 322	1 500
Total area (ha in 10 years)	1 306 472	
Total cost (million MAD in 10 years)		2 286.3

Source: Haut Commissariat aux Eaux et Fôrets et la Lutte Contre la Désertification (2013); PANLCD; national experts in charge of the Souss Massa Drâa and Guelmin Es-Semara project at the MAPM.

In terms of operational costs, it is assumed that there are no significant differences with respect to the business as usual situation, with the exception of rangelands surveillance. Surveillance is taken over by the members of the cooperative with an estimated opportunity cost of USD 2.4/ha (960 person-months/year at USD 300 per month for 120 000 hectares).

With respect to expected benefits, it is difficult to estimate changes in animal production due to improved grazing conditions. Instead, estimates from the MAPM on the incremental value of the forage that is generated in the intervened area were used. Such estimates are expressed in forage units in Table 25, where 1 forage unit in the Moroccan system is equivalent to 1 kg of barley grain. In all cases, the flow of benefits starts 2 years after the intervention and it is assumed to remain constant as long as the grazing management practices agreed amongst the herders are followed.

Table 25: Parameters used for the estimate of benefits generated from the investment in pastureland improvement

	Unit value (USD)	Forage units (equivalent to 1kg of barley grain)/ha/year	Incremental value generated per ha (USD)
From recovered natural and sown pasture	0.3	40	12
From shrubs	0.3	300	90

Source: National experts in charge of the project at the MAPM of Morocco.

Financial returns

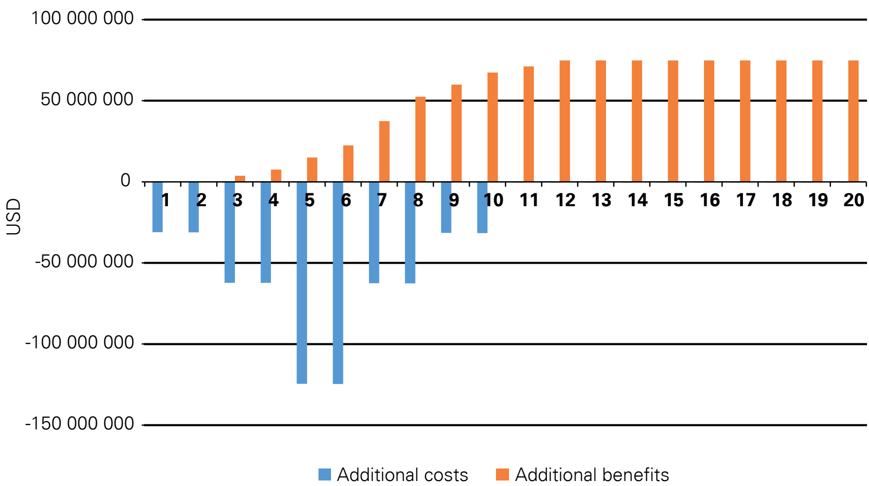
Given the data, a simple model of introduction of improved grazing management practices in Morocco was built with the following key parameters:

- a 20 year time period of analysis following the period of investment;
- financial prices and a financial discount rate of 12 percent;
- investment costs distributed over 10 years with benefits showing 2 years after the investment in each area;
- incremental operating costs consisting of pasture surveillance as described above;
- natural regeneration and constant production of forage for the whole duration of the project for natural pastures and planted shrubs;
- up to 20 years with constant forage production for sown pasture;
- all the initial investment described in Table 25 and the technical assistance on improved grazing management and herder organization is subsidised.

Since all investment is supported by the government, the herders' NPV is positive. However, in a situation in which herders would not benefit from a government project subsidising investment, but only from training and assistance in herders' organization, the NPV would be negative for the given discount rate, USD -103 million or USD -24/ha. The estimated IRR is 6 percent.

The financial attractiveness to herders of improved rangeland management is therefore very limited due to high capital costs and late revenues (Figure 27 summarises the countrywide intervention cash flow). This might partially explain why there is not a wider adoption of improved and sustainable practices of grazing management in the country. In Step 4 other reasons are presented, such as the fact that it requires a high level of organization amongst a large number of stakeholders, or because of the legal framework pertaining to rangelands in Morocco.

Figure 27: Project stream of costs and benefits considered in the analysis



Source: Authors' calculations.

The above results suggest that the feasibility and sustainability of improved grazeland management require strong support for investment and the implementation of additional activities, such as those planned for the project in *Souss Massa Drâa* and *Guelmin Es-Semara*. Investments and activities conducive to value addition to livestock products might (i) increase the value of each forage unit produced in the improved rangelands (e.g. by selling products with a market premium associated with livestock diet enabled by traditional, environmentally friendly systems) and (ii) create a further incentive for sound cooperative management that is necessary both for the vertical integration of herders in value chains and for improved grazing management.

Mitigation cost

Criterion score: *

Economic considerations

The simple financial analysis suggests that subsidies (on investments in physical assets, compensations and technical assistance) play a key role in maintaining improved grazing management practices that are financially attractive to farmers. Considering an economic model identical to that used for the financial analysis, excluding all subsidies and with a discount rate of 8 percent, the intervention returns a negative NPV of USD -41.3 million (USD -9.76/ha). However, important considerations need to be made for a more correct interpretation of the results:

- Improved grazing management produces a great number of positive externalities that are not captured in terms of soil and water conservation, landscape conservation, biodiversity conservation (highlighted in Step 3 of the methodology) and that combat against desertification, all of which will yield important benefits for many generations.
- The project generates a significant amount of quantifiable benefits (in terms of pasture value) in the long-term. It might be that for projects with high long-term environmental and social benefits, lower discount rates would be more appropriate.

Mitigation cost estimate

The mitigation cost in Table 26 was estimated based on the simple financial and economic analysis performed for the intervention foreseen in the PANLCD and on the assumption that the grazeland is moderately degraded and the intervention will help it recover, as previously discussed.

Table 26: Parameters used for the mitigation cost estimate

Parameter	Unit	Value
Intervened area	Thousand ha	4 227
Number of animals affected by the project	Thousand	17 225
Reduction in emissions from enteric fermentation	Thousand tCO_2eq/year	18
Carbon sequestration per year	Thousand tCO_2eq/year	1 100
NPV	Thousand USD	- 41 260
Mitigation cost	USD/tCO_2eq	-1.9

Source: Authors' calculations with data from MAPM (personal communication from experts) and Haut-Commissariat aux Eaux et Fôrets et la Lutte Contre la Désertification (2013).

The estimated mitigation cost for the practice as shown in Table 26 is only indicative as it is based on a number of uncertain variables (particularly potential carbon sequestration per hectare, rate and proficiency of practice adoption, maintenance costs and financial returns). The results suggest that GHG emission mitigation through improvement in grazing management practices might come at a cost to the country. However, considering that there is also a number of positive externalities not accounted for in the numerator (yearly NPV), there is a case for the government to invest in improving degraded rangeland conditions.

Data availability

Criterion score: *

The results presented under each indicator are based on ad hoc surveys or research data from specific projects and are not representative of the whole country. Data on GHG emissions are estimated for generic improvements with internationally used coefficients for the effect of grazing management. No specific information on cost and GHG benefits could be found for Morocco. In fact, the benefit in terms of GHG reduction and sequestration due to rangeland management is not addressed in the latest national communication to the UNFCCC (TCN, 2016).

Manure as soil amendment

Table 27: Summary of the techno-economic criteria scoring for manure as soil amendment in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
***	**	**	***	***	*	*	*

Source: Authors' compilation.

In Morocco, cattle manure that is not left on pasture is typically stocked in unconfined piles with bedding material, while sheep and goat manure is stored in open areas without cover[46]. This means that significant losses through volatilisation and leaching occur during storage; and handling and current practices can be improved to minimise such losses and reduce methane (CH_4) and nitrous oxide (N_2O) emissions from manure management. According to

46 Based on GLEAM-i, 2016. See http://www.fao.org/gleam/resources/en/ for more information.

the Global Livestock Environmental Assessment Model (GLEAM-i) of FAO, chicken farms are already under improved manure management as all broilers' and 10 percent of layers' manure is stacked with litter in deep bedding while 90 percent of the layers' manure is stored in a pit.

As discussed above (introduction to Step 2), manure management can support reduced GHG emissions through, among other things, increasing the frequency of manure removal and preventing leaching and volatilisation from manure. In addition, it can also be processed into biogas and digestate or soil amendments.

Technical assessment

Performance compared with international best practice

Criterion score: ***

Improved manure management, including increased frequency of manure removal from livestock housing, reduced storage time, dedicated storage infrastructure and adequate practices requires simple equipment and knowledge. Most efficient manure management know-how, equipment and facilities are commonly available in the country, although they are not widely adopted as they represent a net cost to the farmer as discussed below.

With regard to the production of soil amendments from manure, there are a few companies in the country that are able to produce quality compost and other bioproducts, including Elephant Vert[47] and Agrifertil[48]. The performance of the technology that can be deployed in Morocco is in line with international best practice.

Maturity of technical support services

Criterion score: **

Technicians in Morocco are familiar with the practices and technology associated with manure collection, handling, treatment and storage; and non-skilled workers can easily adopt them. However, low adoption levels mean that the knowledge and awareness amongst farmers may still be limited.

47 See http://www.elephant-vert.com/le-groupe/qui-sommes-nous/elephant-vert-au-maroc/ for more information.

48 See http://www.agrifertil-maroc.com/ for more information.

Potential to reduce annual GHG emissions

Criterion score: **

GHG emissions from "manure management" normally consist of:

- nitrous oxide gases, released directly from nitrification and de-nitrification processes in the manure;
- methane, produced by anaerobic decomposition of stored or treated manure;
- nitrous oxide gases, released indirectly from nitrogen volatilisation and re-deposition processes;
- emissions from aerobic and anaerobic decomposition processes of leached manure nitrogen from both urine and dung produced by livestock[49].

The above emissions are all considered when assessing emissions from manure management following the IPCC 2007 Guidelines. In Morocco, emissions from manure management in 2012 totalled 3.7 million tCO_2eq according to the current national GHG inventory, corresponding to 16 percent of total agrifood GHG emissions[50]. Emissions from manure management have increased by 158 percent from 2000 and 2012.

Estimates for GHG reduction potential were made considering the following:

- No single figure can be given for the potential to reduce GHG emissions from manure management. There is no specific study for Morocco; and absolute emissions and emission reduction potential differ with local temperatures and aeration, livestock species and diets, etc. However, the FAO paper on Mitigation of Greenhouse Gas Emissions in Livestock Production (FAO, 2013b) cites a number of references and presents a number of estimates of potential emissions reductions from improved manure management. These are: (i) a reduction in net farm emissions of 0.03 tCO_2eq/LU/year based on an assessment of the potential for decreasing GHG emissions from improved manure management practices (enclosed manure storage and burning of captured biogas) in a Holstein dairy farm (Chianese et al., 2009); (ii) estimates of a 49 to 82 percent reduction in overall GHG emissions relative to a reference system – this is due to the separation between solids and liquids, followed by the incineration of the solids in several manure management scenarios using data from four European countries (Sommer et al., 2009);

49 FAOSTAT, 2015: Methods & Standards.

50 There are large differences between FAOSTAT estimates (337 thousand tCO_2eq in 2012) and the Third National Communication of Morocco to the UNFCCC (3.7 million tCO_2eq in 2012). In addition, according to estimates performed with the GLEAM-i (using Tier 2 IPCC), emissions from manure management were 2.3 million tCO_2eq in 2014, somewhat lower than the estimates from the Third National Communication and much higher than those from FAOSTAT.

(iii) a 30 percent emission reduction from manure storage for a number of possible practices[51] with the exception of litter staking (10–30 percent reduction). These practices include decreased storage time, straw-covered storage, natural or induced crust, aeration during liquid manure storage and litter stacking or controlled storage temperature.

- FAOSTAT provides figures for the number of animals in the country and GLEAM-i provides estimates on the number of animals for which manure is collected and managed and the practices currently in use. The information is complemented by the volume of manure considered per LU and is summarised in Table 28.
- Estimates of the potential to reduce annual GHG emissions can be made by applying a reduction coefficient to the number of LUs for which manure is managed (Table 28) and considering a share of emissions that can be reduced from the total emissions from livestock management.

Table 28: Estimate of number of livestock units (LU) with manure management and potential volume of manure for improved manure management practices in Morocco, 2013

Species	Heads for which manure is managed	Coefficient LU/head	Number of livestock units (thousands)[a/]	Share of manure considered for management (%)	Number of livestock units considered for management (thousands)[a/ b/]	Volume of manure considered for manure management (thousand tonnes/year)[a/ b/]
Cattle	3 172 980	1.0	3 170	60	1 900	22 800
Goats	6 235 860	0.1	620	50	310	3 720
Sheep	19 956 380	0.1	2 000	50	1 000	12 000
Layers	21 990 000	0.014	310	90	280	3 360
Broilers	40 627 000	0.007	280	100	280	3 360
Total (rounded figure)			6 384		3 770	45 240
Total with potential for improved management (excluding layers and broilers) (rounded figure)			5 790		3 210	38 520

Source: FAOSTAT (2016) for number of head; GLEAM-i (2016) for share of manure considered for management; national expert's research for tonnes of manure per livestock unit; and authors' calculations.

Notes: [a/] Manure from layers and broilers is already under improved management practices (pit storage and litter stacking) and is not considered has contributing for the potential for improved management.
[b/] Rounded figures.

51 As listed in FAO, 2013b, Appendix 2-Table 2.

Using the information in Table 28 and the above estimates from the literature on potential emissions reduction per LU, a range of annual emissions estimates can be calculated. The range is dependent on the type of data used and is quite broad: the potential GHG reduction from improved manure management is between 96 thousand and 1.1 million tonnes CO_2 equivalent. The following two key approaches were used:

(i) Applying the coefficient of 0.03 tCO_2eq/LU/year from Chianese et al. (2009) to the number of LUs for which manure is managed and improved management practices can be applied (around 3.2 million LUs), the potential to reduce emissions is 96 300 tCO_2eq/year, corresponding to less than 1 percent of agrifood sector emissions, or 3 percent of manure management emissions (3.7 million tCO_2eq/year).

(ii) Using data on total emissions from manure management as estimated in the country's National Communication to the IPCC (2016) – 3.7 million tCO_2eq/year – and applying a 30 percent reduction results in a drop of 1.1 million tCO_2eq/year, or 4.7 percent of agrifood sector emissions.

In addition to the good manure management practices illustrated above, the effects of composting manure are considered. This additional climate technology can displace synthetic fertiliser production more than the direct application of fresh manure, which has different possible uses and characteristics. The potential to reduce GHG emissions through the production of compost also depends on the current livestock systems in the country (compost can only be produced if manure is easily available).

A quick assessment of the scale of mitigation potential from composting in Morocco is made assuming the following:

- emissions resulting from the application of compost to soils (mostly due to leaching and volatilisation), i.e. 6.9 tCO_2eq/t N applied, and the application of synthetic fertiliser, i.e. 6.5 tCO_2eq/t N applied)[52], are similar, and therefore are not considered in the emissions assessment;
- according to FAOSTAT, the quantity of nitrogen in managed manure volumes in Morocco is 31 814 tonnes (2012 numbers);
- emissions saved from avoiding the production and transport of synthetic fertilisers to the farm-gate by applying compost instead are as estimated by Kool (2012) (5 tCO_2eq per tonne N[53] using the world average urea production).

52 Based on FAOSTAT, 2015 (GHG emissions domain).

53 Database used by FAO LEAP: Kool et al., 2012: p.9, Table 13. This figure includes transport, although this accounts for a minor share of emissions.

The maximum annual GHG emissions reduction that could be obtained from the displacement of synthetic fertiliser by composting would only be 31 814 tonnes N multiplied by 5 tCO_2eq per tonne N, yielding almost 160 thousand tCO_2eq or 0.7 percent of the emissions from the agrifood sector. This estimate was found based on the above assumptions, excluding emissions from transport and compost production, and ignoring the fact that the nitrogen of the compost displaces a similar quantity of nitrogen from synthetic fertiliser.

Combining all of these results, the analysis suggests that improved manure management practices and composting could reduce emissions in the range of 0.3 to 1.3 million tonnes of CO_2eq per year (using the manure emission data from the national GHG inventory): between 1 and 5 percent of total annual agrifood sector emissions.

Market assessment

Current technology adoption rate

Criterion score: ***

No figures could be found to estimate the adoption of improved manure management practices in Morocco. From the literature (GIZ, 2014) and discussions with local experts (namely at IAV Hassan II) we can assume that there are some initiatives present in the country, but adoption is still in its infancy. Using the estimates from Table 28 based on FAOSTAT data, there are 45.3 million tonnes of manure managed each year in Morocco, of which roughly 38.5 million tonnes (85 percent, or all available manure with the exception of that from broilers and layers) could still be managed under improved practices.

Without new regulations or financial incentives to promote manure management, adoption of improved practices is to a great extent dependent on the development of legislation to safeguard the environment or a market for compost (assuming that this industry somehow compensates the farmers for the costs of improved manure management). As of today, the value addition of agri-residues, and manure in particular, to produce compost is an emerging economic activity in Morocco with just a few producers identified throughout the country. However, the market for compost is potentially very large since the vast majority of soils in Morocco lack organic matter and the industry has an opportunity to develop.

During the field work conducted as part of this rapid appraisal, meetings with local firms[54] suggested a total national production of around 40 thousand tonnes of compost per year and 500 million tonnes of organic waste. In order to achieve this compost production figure, around 200 thousand tonnes of organic

54 In particular, meeting with Elephant Vert, a company based in Meknes that produces around 20–25 000 tonnes of compost per year.

residues (not just manure) are estimated to be handled and treated each year, chiefly agri-residues (around 50 thousand tonnes per year are currently treated just in the Meknes region). Hence, the current production of compost would account for just under 0.1 percent of its technical potential.

Trends in gap between current technology uptake and technical potential

Criterion score: ***

Improved climate practices to collect, handle, treat and store manure are rarely applied in Morocco, while the total livestock herd is increasing in size and production systems are intensifying. No data exists on manure management practices other than composting. Regarding composting from manure, besides Elephant Vert – which started operations 2 years ago with a production of around 10 thousand tonnes per year and reached 20 to 25 thousand tonnes per year at present – only small producers exist. These smaller producers also started their operations relatively recently (7–8 years ago).

The gap between the current uptake and the technical potential of the practices associated with manure management is large and will likely increase in a "business as usual" scenario within an expanding livestock sector.

Economic assessment

Financial attractiveness

Criterion score: *

Financial costs and benefits

As mentioned before, the opportunities to improve manure management lie both in its handling and treatment (in the case of this note, composting). The analysis below lays out simple models drawn from the literature to illustrate these cases.

As mentioned before, climate friendly manure management practices are not common in Morocco for cattle, sheep and goat farms. Hence, technical coefficients and financial data for specific, let alone representative, cases in Morocco could not be obtained. The analysis presented below must be interpreted considering that:

- Investment in collection, storage, handling and treatment equipment is drawn from an experience in Iowa, USA, where the practices of 22 dairy producers were surveyed and costs of storing, hauling and treating (composting) manure were collected. Given that most equipment in Morocco would be imported or would have to compete with imported goods, and in absence of additional data, the investment costs in Morocco were assumed to be the same. Table 29 presents the average investment per cow on equipment and adequate storage facilities.

- Total annual operational costs of manure management including on-farm composting were drawn from the Iowa experience and adapted to the national labour costs and practices through discussions with experts in Morocco.

Table 29: Manure management costs for dairy cattle

Investment/cost items	Unit	Value
Costs of collection, handling, and storage		
Investment in collection and storage equipment (on-farm)*	USD/LU	110
Total annual operational costs+	USD/LU/year	20
Costs of composting on-farm		
Investment in handling and treatment equipment*	USD/LU	45
Total annual operational costs+	USD/LU/year	40
Annual estimated income from compost sales+	USD/LU	75

*Source: Authors' calculations based on *Bentley et al. (2014) and +A. Araba (national expert on livestock)[55].*

Financial returns

There is no financial compensation for farmers from improved manure management practices, which will always come at a cost. Compost, on the other hand, has a market value and can bring returns to operators. A simple model consisting of the investment and operational costs from Table 29, a 10 year period of analysis and a 12 percent discount rate would yield an NPV of USD 300/LU and an IRR above 70 percent. However, if the two practices (improved collection, handling and storage plus composting) are implemented together, the combined NPV would be negative (USD -63/LU).

Since composting can be undertaken virtually independently from other manure management techniques, the returns on the former do not necessarily result in additional incentives for improvements on the latter depending on the system used. In some cases, however, a composting activity may lead to a reduction in the period of manure storage (possibly unconfined storage) and this can yield GHG emission reduction benefits.

55 Resulting from interviews held in Morocco during the rapid appraisal mission.

Mitigation cost

Criterion score: *

Economic considerations

The estimate of economic indicators (IRR and NPV) used the same prices as the financial analysis, but an SDR of 8 percent, i.e. the NPV, was estimated using a simple model. The model considered the investment in equipment for collection, storage and handling, the respective annual operation costs as in Table 29 and a 10 year period of analysis. The resulting NPV for collection, handling, and storage alone is USD -226/LU or USD -22.3/year/LU. However, there are a number of factors that could not be internalised in the estimated NPV and are important to consider, such as adequate manure management to reduce odours and soil contamination (see Step 3 for additional information on positive externalities).

Even considering that it comes as a financial cost, once positive externalities are considered, national investment in improved manure handling and storage practices (and other livestock-related practices) may be worthwhile. For example, after a set of specific studies on cattle farming, the Irish government recognised that the net benefit of decreasing the carbon footprint of cattle farms in the country went beyond the financial return that some climate friendly practices could bring to the farmers. As such, it created a certification scheme (Origin Green) for farmers who abide by established good practices in energy usage, emissions, waste, water use, animal welfare, biodiversity and social sustainability (Origin Green, 2016). The necessary investment costs for practice adoption are partially subsidised by existing government programmes. The budget associated with Origin Green initiatives provides technical support and certification services to the farmers and advocates the Origin Green certification to the general public in order to generate a market price premium for the certified products.

The Irish example provides an interesting case but since manure management and storage can become a substantial aggregate financial cost, Morocco may not see it as a priority for the reduction of GHG emissions. Also, the large emissions from cattle in Ireland and thus the large mitigation potential may be higher than other countries where livestock is kept less intensively (see the estimated mitigation costs for Morocco below).

The economic benefits from composting are hard to estimate but they are clearer. In addition to the financial benefits estimated above, compost may reduce the spread of weeds and diseases in crops and be a better contributor to soil fertility vis-à-vis the direct application of manure. The economic NPV of investing in the complete set of manure management practices – improved collection, handling and storage and composting – is USD -50/LU or USD -5/LU/year.

Mitigation cost estimate

The mitigation cost was calculated for collection, handling and storage alone and for these practices combined with composting. The parameters and assumptions used for the estimate of the mitigation cost are shown in Table 30.

Table 30: Estimate of the mitigation cost

Source	Estimate of mitigation costs	Unit	Value
(a) FAOSTAT	Livestock in Morocco with manure management	Thousand LU	3 210
(b) National GHG inventory 2016	Total livestock emissions from manure management	Thousand tonnes	3 656
(c) Earlier estimates	NPV from collection, handling and storage	USD/LU	-226
(d) Earlier estimates	NPV from collection, handling and storage and composting	USD/LU	-50
(e) = a*c/10	NPV from collection, handling and storage	USD million/year	- 72.6
(f) = a*d/10	NPV from collection, handling and storage and composting	USD million /year	-16.2
(g) = e/b	**Cost of mitigation for collection, handling and storage**	**USD/year/tCO_2eq**	**66**
(h) = f/b	**Cost of mitigation for collection, handling and storage and composting**	**USD/year/tCO_2eq**	**13**

Source: Authors' calculations from FAO (2013b); GLEAM-i (2016); Bentley et al. (2014); A. Araba (national expert on livestock).

As the results suggest, mitigation through on-farm improved manure management practices will need incentives that are not currently present in the Moroccan context. Regarding the economic benefits from composting organic residues beyond manure, it should be noted that they go beyond just an alternative to chemical fertilisers, since countries such as Morocco bear a cost from importing nitrogen fertilisers and disposing the organic waste in landfills. The total cost to society would be smaller if the organic waste could be treated and diverted for compost instead of being disposed of in landfills[56].

56 According to Elephant Vert, Morocco is paying around 1.2 million dirham for nitrogen fertiliser imports and around 1 million dirham for landfill and organic waste disposal. Diverting the same amount of organic waste to compost would cost around 1.5 million dirham, which is less than the sum of the other two.

Data availability

Criterion score: *

Data on GHG emissions from manure management largely differs depending on the source, reflecting the difficulty in the assessment of manure management-related GHG emissions. The potential for mitigation also depends on the context and no countrywide assumptions can be made with precision. Information on the type of equipment available for manure management and of its costs would only be available if collected through ad hoc surveys or research, which are not within the scope of this report.

Other information, such as agri-residues and manure available for transformation into more valuable products, as well as the amount of bioproducts produced in Morocco, is available from private sector market studies since only a few companies currently operate in the sector.

Livestock dairy breeds on improved diets

Table 31: Summary of the techno-economic criteria scoring for livestock dairy breeds on improved diets in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
**	**	*	**	**	***	***	**

Source: Authors' compilation.

Ruminants including cattle, buffalo, sheep and goats normally have the highest methane emissions among animals because of their unique digestive systems. According to FAOSTAT, in 2012 cattle (both dairy and non-dairy) were responsible for approximately 45 percent of total emissions stemming from livestock enteric fermentation in Morocco, followed by sheep (36 percent) and goats (11 percent). Dairy cows[57] in particular accounted for the bulk of emissions from total cattle enteric fermentation with some 60 percent, or roughly 1 500 Gg Co_2eq out of 2 450 Gg CO_2eq.

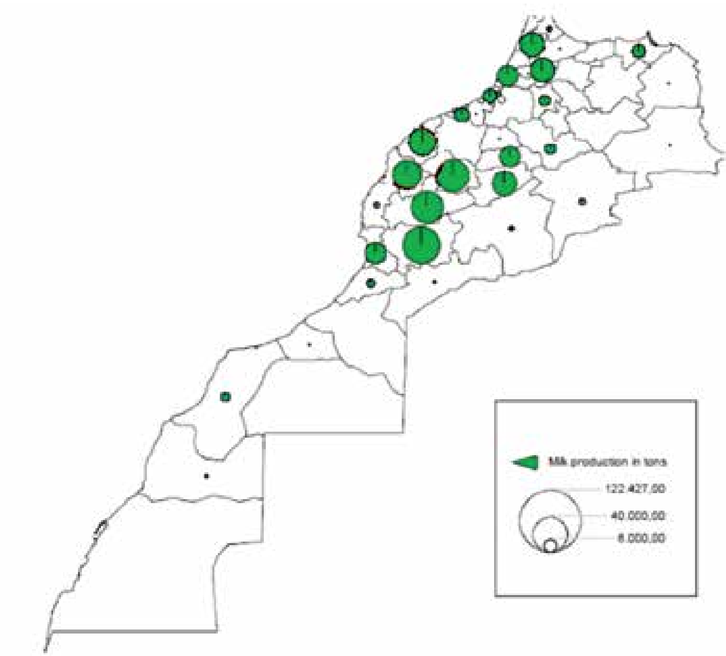
There is a notable potential to reduce emissions from enteric fermentation in dairy cows. More specifically, this assessment considers the mitigation potential for interventions that reduce emissions per litre of milk produced. Such reductions can be produced by: (i) a shift to more productive breeds; and

57 In FAOSTAT, dairy cattle data are expressed as heads of cows producing milk.

(ii) the improvement of the cows' diet (mostly by adjusting quantities to increase milk productivity). This note does not assess changes in the global life-cycle[58] of the dairy sector, but only in enteric fermentation[59].

Milk production is concentrated in the northwestern part of the country (Figure 28), where the main production areas are Loukkos, Gharb, Tadla, Doukkala, Haouz and Taroudant, with highly favourable agro-ecological conditions.

Figure 28: Distribution of milk production in Morocco



Source: National Statistics Bureau, Morocco, 2008.

58 The global life-cycle includes the production of feed, emissions from animal production, emissions related to processing and transportation of product to the distribution point (FAO, 2013b).

59 Global life-cycle assessments (FAO, 2013a) place emissions per kilogram of milk in a range from 1.3 (in industrialised regions) up to 9 kg CO_2eq (in low productivity regions). The North African average is 4.6 kgCO_2eq/kg (FAO, 2010). No exact statement can be made on real global life-cycle emissions in Morocco in the absence of life-cycle assessments, but these could be as much as three times the values shown in our assessment for enteric fermentation.

Technical assessment

Performance compared with international best practice

Criterion score: **

When using international best practices, yields can be up to 8 000–11 000 kg milk/cow/year (DEFRA, 2015; CRV, 2014); but this is generally found in environments different from Morocco, where few dairy operations can be found with yields above 6 000 kg milk/cow/year. The best domestic results are seen on irrigated farms in the Taroudant region with production of over 6 800 kg milk/cow/year, as reported by national experts. Thus, there are high-performing dairy farms in Morocco.

However, FAO (2011) reports that of approximately 750 000 cattle farms in Morocco, only 5 percent are specialised dairy farms with highly productive cows (mostly Holstein and Montbéliarde). The remaining cattle farms are dual-purpose and herds are generally composed of local breeds or crosses between local breeds and Holstein. Dual-purpose farms are mostly beef-oriented as local cattle breeds rarely produce more than 500 kg of marketable milk per lactation.

Although high-yield dairy farms are rare in Morocco, given that some do produce over 6 000 kg milk/cow/year and employ the most efficient technology, we are considering national best practices close to international standards for this analysis.

Maturity of technical support services

Criterion score: **

The top dairy technology is widely known to relevant technical institutions in the country and practiced by a number of milk producers. However, wider adoption would require special skills and knowledge that are still lacking in the country, especially among farmers but possibly also amongst some technicians and extension workers. Technical assistance is required for a faster change in feeding practices and the assessment of yield improvements.

Potential to reduce annual GHG emissions

Criterion score: *

Although it is technically possible to reduce enteric fermentation while keeping the milk yield constant, this entails more expensive feeding practices than the ones that are generally in place in Morocco. Hence, dairy farmers are only incentivised to adopt a different technology if the new one will increase milk productivity enough that it more than offsets the associated costs. For this reason, this analysis assesses non-technological changes such as adjusted diets and different breed compositions that could increase milk production while reducing enteric fermentation emissions per litre of milk. Based on this, the estimate of the GHG reduction potential builds on the following data and assumptions:

- total cattle population is 3.2 million heads in Morocco (MAPM, 2014), comprising some 1.3 million heads of local cattle breeds (40 percent), 0.9 million heads of crossbred cattle (33 percent), and about 1 million heads of pure cattle breeds (27 percent);
- the total number of dairy cows (female) in Morocco in 2012 was about 1.56 million heads (FAOSTAT);
- the distribution of dairy (lactating) cows amongst breeds is considered to be the same as for the whole herd, i.e. 40 percent local, 33 percent crossbred and 27 percent purebred;
- national milk production in 2012 stood at 2.5 million tonnes (FAOSTAT)[60];
- total emissions from enteric fermentation of dairy cows totalled 1.5 million tonnes of CO_2eq in 2012 (FAOSTAT), or an average of 0.6 tonnes of CO_2eq per tonne of milk;
- a projected scenario of improved breed and diets would consist of: (i) a 30 percent decrease in the number of local breeds[61]; (ii) a 15 percent increase in the number of crosses of local breeds with pure dairy breeds; and (iii) a 15 percent increase in the number of pure dairy breeds;
- an average increase of 15 percent in the quantities of feed provided to crosses and 30 percent in purebreds along with an improvement in infrastructure and sanitary and hygiene conditions;
- a 50 percent increase in the national average milk yield per cow, in which local breeds would not see changes to their current average yields (300 kg milk/cow/litre), and purebreds would increase at a slightly higher percentage than cross breeds;
- a 1.4 percent potential GHG emission reduction per cow due to improved feeding practices and structural changes in animal breeding (Smith et al., 2013).

60 The MAPM reports 2 400 000 litres for 2014. However, the latest available FAOSTAT data were used instead as they have the complete set of information (number of dairy cows, enteric fermentation of dairy cows and milk production) required for this analysis.

61 Local breeds predominate in dual-purpose, mostly beef-oriented, farms (FAO, 2011). Many of the farms under a dual-purpose system face severe feed constraints, thus an upgrade to specialised dairy farms is most likely to occur on farms within irrigated schemes. FAO (2011) reported that there were 400 000 lactating cows on irrigated dual-purpose cattle farms in Morocco.

The improved feeding practices and structural changes in animal breeding would result in an average reduction of between 0.39-0.6 tonnes of CO_2eq per tonne of milk[62] as summarised in Table 32.

Table 32: Changes in the average emissions per litre of milk in national herd

	Current situation	Improved breeds and diets
Total number of lactating cows	1 555 000	1 509 000
Total milk production (tonnes)	2 500 000	3 639 000
Total emissions (tCO_2eq) – reduction of 1.4%/animal	1 500 000	1 437 000
Emissions per litre of milk (tCO_2eq/tonne milk)	0.60	0.39

Source: Authors' calculations based on FAOSTAT data (2012).

Note: Figures are rounded.

The estimate of the potential to reduce annual GHG emissions is made assuming:

- a "business as usual" scenario in which the current quantities of milk (2.5 million tonnes) are produced with an emission factor of 0.6 tonnes of CO_2eq per tonne of milk;
- an improved scenario in which the total production of milk is produced with an emission factor of 0.39 tonnes of CO_2eq per tonne of milk;
- the incremental production of milk in the improved scenario would replace regular milk with the same emission factor (0.39 tonnes of CO_2eq) as it is reasonable to assume that most of the increase in a "business as usual" scenario would be achieved by incrementally increasing the existing herd with highly productive, adequately fed cows and therefore a low emission factor – or by replacing already efficiently produced imported milk.

The estimate of the potential to reduce annual GHG emissions under these scenarios is summarised in Table 33.

62 Emissions due to enteric fermentation from dairy cattle in Portugal, Israel, Algeria and Lebanon reported on average some 0.3 tCO_2eq/tonne of milk for 2012 (FAOSTAT), signalling that the estimated average for an improved scenario for Morocco is realistic. The improved scenario is also consistent with the past trends depicted in Figure 29.

Table 33: Estimate of the potential to reduce annual GHG emissions from enteric fermentation in the dairy sector

	Business as usual scenario	Improved scenario
Current quantity of milk (tonnes)	2 500 000	2 500 000
Current quantity emission factor (tCO_2eq/tonne milk)	0.60	0.39
Emissions for current quantity of milk (tCO_2eq/year)*	1 502 000	987 222
Total emissions reduction (tCO_2eq/year)		515 000
Total emissions from the agrifood sector (tCO_2eq/year)		23 400 000
Emissions from the agrifood sector – reduction potential		2.2%

Source: Based on FAOSTAT, 2015.

* There is no change in emissions from the incremental production of the improved scenario, as the emission factor of this production is assumed to be the same as the milk it substitutes.

Note: GHG emissions of the agricultural sector are taken from the national GHG inventory. Data refer to 2012. Figures are rounded.

In addition to the benefits in terms of enteric fermentation emission reduction, improved breeds and feeding practices are also expected to decrease emissions from manure left on pastures since better diets should gradually shift grazing/pastoral systems towards feedlot systems, implying superior manure collection practices[63].

Market assessment

Current technology adoption rate

Criterion score: **

Our assessment based on FAOSTAT considers a dairy cattle stock of about 1.56 million heads. Of this total, 400 000 heads (26 percent) are on irrigated dual-purpose farms, which can potentially see a structural improvement in their animal breeds and benefit from improved feeding practices. Additionally, purebred dairy cows – 0.42 million, or 27 percent of the total dairy cattle herd – can benefit from improved feeding practices.

63 Although this is significant, the effects of manure left on pastures are not addressed in detail since a proper GHG emission balance should also consider the additional emissions associated with the production of feed crops grown for concentrates (maybe in another country), which falls beyond the scope of this work.

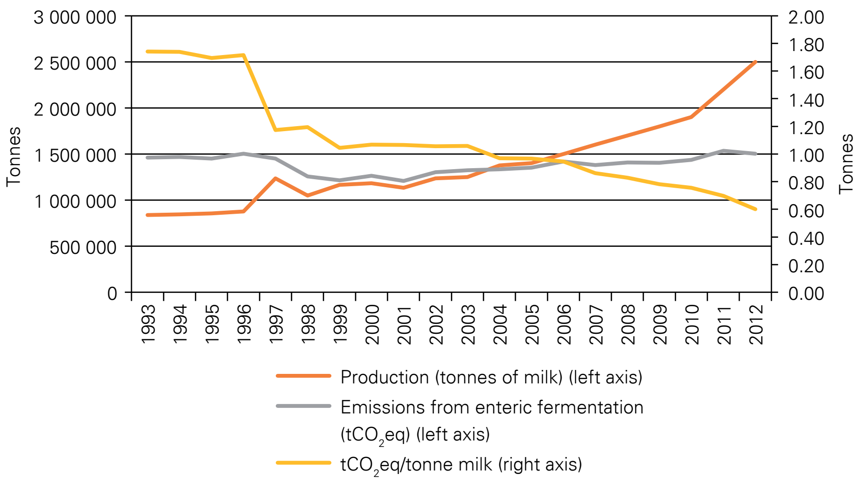
Trends in gap between current technology uptake and technical potential

Criterion score: **

According to statistics from the MAPM of Morocco, in the early 1970s, pure and crossbred dairy cattle represented about 2 percent of the total (including dairy) population in the country (DDFP/MAPM, 2015). This share has increased to 60 percent of the current 3.2 million heads, with the remaining 40 percent comprising different cattle local breeds, mainly Brune de l'Atlas (1 100 000), Oulmes Zaer (80 000), and Tidili (20 000).

Similarly, milk yields in Morocco have shown steady improvements (Figure 29), mostly due to the gradual (structural) change in cattle breeds. This was also due to the diversification and improvement of feed resources, and the implementation of milk collection infrastructure. Should this trend continue, the existing gap between pure and crossbreeds and respective diets would still be relevant but is expected to reduce over time.

Figure 29: Trends in the Moroccan milk sector production, 1993–2012



Source: FAOSTAT, 2015; authors' calculation.

Economic assessment

Financial attractiveness

Criterion score: ***

Financial costs and benefits

Three situations adapted from farm models found in the literature (FAO, 2011 and Baali et Raki, 1998) were modelled for a simplified financial analysis:

- a specialised farm composed of 20 purebred cows would improve the animals' diets;
- a specialised mixed farm (5 purebred and 3 crossbred cows) would improve feeding practices and substitute crosses with purebreds;
- a dual-purpose irrigated farm with 5 local breed cows, which would be upgraded to a specialised mixed farm (5 purebred and 3 crossbred cows) with improved feeding practices.

Table 34 summarises the data and assumptions used to assess the financial attractiveness of changes in herd breed composition and diet in the three proposed models. Additional assumptions used to construct three farm models are as follows:

- specialised dairy farms require one semi-skilled labourer per 15 cows;
- dual-purpose irrigated farms require one unskilled labourer per 5 cows;
- additional operating costs of 2 percent of the total operating costs;
- a *Fonds de Développement Agricole* (Agricultural Development Fund, FDA) subsidy of USD 500/head for the acquisition of purebred cows;
- culled cows are worth the same as a calf of the same breed;
- all conversions require an investment in infrastructure that corresponds to 4 m^2/cow with a cost of USD 80/m^2[64];
- dairy farm infrastructure benefits from a subsidy corresponding to 25 percent of the acquisition and installation cost.

There is also a subsidy of MAD 2 000/head in place for the rearing of crossbred calves until 8 months of age (industrial crossbreeding), but this was not included in the calculations since the models assume the new cows are bought at 3 years of age.

64 This corresponds to the maximum cost for covered stalls benefiting from a 25 percent subsidy from the FDA. However, depending on the case, farms may need lower investments in infrastructure and considerable investments in farm equipment such as silage equipment, forage mixers, etc. (Dairy farm equipment is subsidised 30 percent by the FDA.) Hence, the investment costs used in the models aim to be an approximation and are not representative of the real needs of the average farm.

Table 34: Summary of the financial analysis on changes in dairy cattle genetic composition and diet

Variable	Units	Current situation				Projected scenario			
		Local	Crosses	Holstein	Overall	Local	Crosses	Holstein	Overall
Improvement in feed compared to current situation					-	0%	15%	30%	
Purchase price of replacement dairy cow (investment)	USD/cow	1 000	1 700	2 700	1 691	1 000	1 700	2 700	1 819
INPUTS (OPERATIONAL COSTS)									
Quantity of forage produced on-farm	kg/cow/yr	1 500	3 650	7 000	3 697	1 500	4 198	9 100	4 991
Production costs of forages	USD/kg	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
On-farm produced forage cost/cow/yr	USD/cow/yr	83	203	389	205	83	233	506	277
Quantity of forage off-farm	kg/cow/yr	500	1 000	1 000	800	500	1 150	1 300	1 011
Off-farm forage price	USD/kg	0.11	0.09	0.09	0.09	0.11	0.09	0.09	0.09
Off-farm forage purchase cost	USD/cow/yr	56	89	89	75	56	102	116	94
Quantity of concentrate fed to cows	kg/cow/yr	0	1 000	2 000	871	0	1 150	2 600	1 283
Concentrate price	USD/kg	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Concentrate cost	USD/cow/yr	0	333	667	290	0	383	867	428
Veterinary expenses	USD/cow/yr	0	22	44	19	0	22	44	23
Total operational costs	**USD/cow/yr**	**139**	**647**	**1 189**	**590**	**139**	**741**	**1 532**	**822**

OUTPUTS (INCOME)									
Average milk yield	kg/cow/yr	300	1 708	3 416	1 608	300	2 135	4 612	2 400
Farmgate price of milk	USD/kg	0.35	0.37	0.37	0.37	0.35	0.37	0.37	0.37
Income from milk	USD/cow/yr	105	632	1 264	595	105	790	1 706	888
Income from calf sales	USD/cow/yr	450	700	900	654	450	700	900	692
Total income	**USD/cow/yr**	**555**	**1 332**	**2 164**	**1 249**	**555**	**1 490**	**2 606**	**1 580**
Gross margin (including calf sales)	**USD/cow/yr**	**416**	**685**	**975**	**659**	**416**	**749**	**1 074**	**758**

Source: Authors' compilation from projections made for the national dairy herd improvement strategy; FAO, 2011b; FAOSTAT, 2015.

Financial returns

The results are encouraging, as the analysis yields an NPV for a period of 10 years and a 12 percent discount rate of:

- USD 5 000 (IRR 37 percent) for the specialised farm composed of 20 purebred cows improving the animals' diets – without subsidies the IRR would be 26 percent;
- USD 2 000 (IRR 21 percent) for the specialised mixed farm substituting crosses with purebreds and improving feeding practices – without subsidies the IRR would be 18 percent;
- USD 7 300 (IRR 24 percent) for a dual-purpose irrigated farm specialising in dairy with 5 local breed cows – without subsidies the IRR would be 17 percent.

The analysis suggests that current subsidies play an important role in providing incentives to improve milk production systems, although small farmers practicing the most common dual-purpose system still require considerable initial capital costs for conversion (USD 15 000 in the model), which may constitute too high of a barrier to change. Additionally, the proposed changes imply an increased production of forage, which may mean a change in cropping systems not adequately conveyed in the price of forage, or an increase in water requirements in already water-scarce systems.

Mitigation cost

Criterion score: ***

Economic considerations

A simple economic model was built based on the assumptions summarised in Table 34, plus those listed in the sub-section "Potential to reduce annual GHG emissions". The investment and labour costs were considered to be the same as in the financial analysis (without subsidies).
Under these assumptions, a structural change in breeds and an improvement in feeding practices, the corresponding increase in production would result in an NPV of USD 240 million (period of 10 years and discount rate of 8 percent) and an IRR of 20 percent.

Mitigation cost estimate

An economic NPV of 240 million for a 10 year period and a potential to reduce GHG by 515 000 tCO_2eq/year means a mitigation cost USD -46/year/CO_2eq.

Data availability

Criterion score: **

Data on livestock, especially dairy productivity and cost-benefit analyses, are readily available from high level sources in Morocco. However, the data are not disaggregated by breed and the analysis was performed using assumptions based on expert opinions. Additionally, no on-site studies on GHG emissions associated with changes in livestock breeds and diets are known or could be used. This analysis relied heavily on the GHG domain of FAOSTAT, which provides detailed estimates following IPCC Guidelines at Tier 1 of emissions associated with dairy cattle.

Efficient water boilers

Table 35: Summary of the techno-economic criteria scoring for efficient water boilers in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
**	**	*	**	**	**	***	*

Source: Authors' compilation.

As mentioned in Step 1, process heat is generally the main energy demanding activity in the food process industry, usually exceeding half of the end use energy demand, followed by refrigeration, motor drives and ventilation (FAO/USAID, 2015). Steam generating water boilers are major energy consumers and thus large CO_2 emitters.

Water boilers used in the food industry are usually small- to medium-sized boilers not exceeding 2 t/h of steam, most of them being produced in Morocco. The number of boiler suppliers and companies able to design, install and maintain water boilers is not large: one major local producer of small and medium boilers and a few companies importing equipment from abroad.

The vast majority of water-tube boilers in the Moroccan food industry use fuel oil as an energy source, some of them inefficiently. According to industry sources, around one-third of all small- to medium-sized boilers used in Morocco today are not energy efficient and would benefit from improvements.

There are no public incentives or regulatory measures to promote energy efficiency for boilers in the food processing industry. Maintenance to keep boilers clean and well-functioning is kept to a minimum and boilers are usually used until the end of their economic life, 5 to 10 years, depending on the type of maintenance performed. Additionally, the market of low-performance second-hand boilers in Morocco is significant (mainly old boilers are imported from Europe) and this market further decreases the overall performance.

Small water boilers below 1 000 KW may use diesel or LPG as their energy source in Morocco, while medium-sized boilers (typically above 1 500 KW) use fuel oil. The latter account for the vast majority (around four-fifths of the total).

Technical assessment

Performance compared with international best practice

Criterion score: **

The major national producer and installer of small-medium boilers in Morocco, with a market share of around 80 percent (i.e. the vast majority of boilers used in the agrifood sector), reports that new boilers typically have 88 percent energy efficiency[65]. This is just a couple of percentage points below the performance levels achieved in international markets (IEA-ETSAP, 2010). The gap is mainly due to the fact that capital-intensive machinery would be needed to align the national boiler industry with international best practice, which is not available as of today. However, differences in energy efficiency are usually more related to maintenance and age of the boiler than design. The best available technology can be imported, but it is costly.

65 The energy efficiency of a boiler is measured as the ratio of heat in steam output to heat in fuel input.

Maturity of technical support services

Criterion score: **

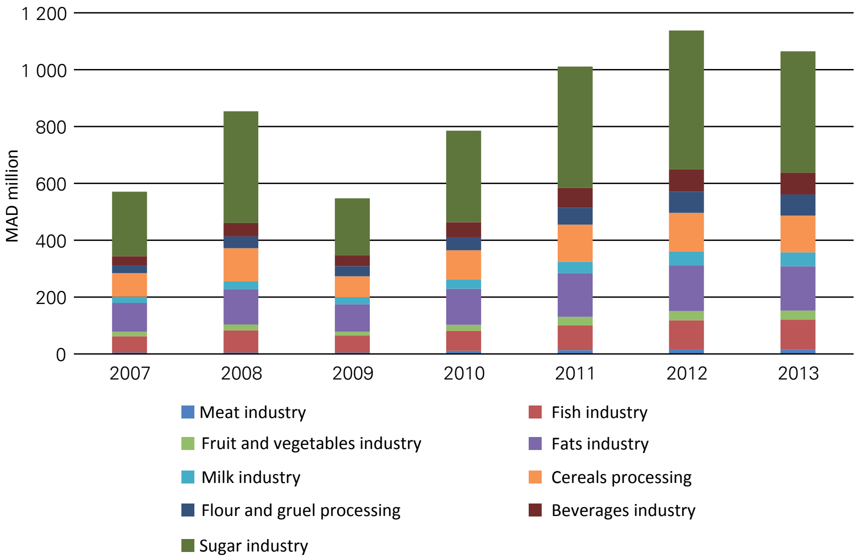
Technical support to water boilers used in the food industry is available in the country and most operators can use efficient boilers without specific skills. However, only a few specialised companies exist for manufacturing and installation of water boilers.

Potential to reduce annual GHG emissions

Criterion score: *

Based on national accounts (HCP), it is estimated that in 2013 around 245 million litres of fuel oil were consumed by the food industry – 150 million litres excluding the sugar industry (Figure 30), a major fuel oil consumer that uses large and high performance boilers and was consequently excluded from the analysis.

Figure 30: Fuel oil consumption in the food sector by subsector, 2007-2013



Source: HCP, 2015.

Considering: (i) a consumption of 150 million litres of fuel oil by small and medium water boilers in the agrifood industry; (ii) one-third of the boilers in use are inefficient; and (iii) there are efficiency increases of 10 to 15 percentage points[66] (12.5 percentage points is used in the calculation) when switching from old to new boilers, it is estimated that around 6 million litres of fuel oil could be saved every year by replacing old boilers in the food industry. This corresponds to more than 18 thousand tCO_2eq, or less than 1 percent of the total agrifood sector GHG emissions.

It is important to note that, according to *Bureau Veritas-Maroc*, a certification company working on energy audits, the number of small- and medium-sized water boilers operating in the food industry in the country would not be over 2 thousand. Assuming this number of boilers and the total fuel oil consumption reported by the HCP, each boiler would work on average just 80 days per year[67]. These figures signal that an accurate assessment of the potential to reduce GHG emissions from improved efficiency in industrial boilers would require a survey.

Market assessment

Current technology adoption rate

Criterion score: **

According to most accounts[68], around two-thirds of the boilers currently in use in the food industry are regularly maintained and can be considered "efficient" from an energy point of view. The remaining one-third would need refurbishment/replacement.

The market for the technology is quite mature (at around two-thirds of its potential) and it cannot be considered "new". However, there is still room for improvement and expansion of the technology.

Trends in gap between current technology uptake and technical potential

Criterion score: **

The import of second-hand boilers – often not declared as boilers at customs and therefore not entirely covered by official statistics – is an increasing phenomenon, which lowers the overall energy efficiency of the boilers in use. However, the general trend is that the food industry is expanding and so are water boilers used for food processing, which are usually new efficient boilers and not second-hand ones. Hence, there is an important gap between the total number of boilers and those that are high-performing – estimated at one-third of the boilers – and this gap seems to be, at most, reducing slowly over time. In

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66 See US EPA, 2010 (Table 1) for a detailed description of the possible single energy efficiency and GHG reduction measures and the corresponding efficiency improvement achievable.

67 Estimate made for 700 kWh boilers with 84 percent fuel oil use efficiency (considering one-third with 76 percent and two-thirds with 88 percent efficiency as reported by the industry) functioning 12 hours per day.

68 Based on discussions with local energy audit firms and equipment suppliers.

addition, new and more efficient boilers are constantly being developed, which translates into the need for constant upgrades to keep efficiency levels close to international standards.

Economic assessment

Financial attractiveness

Criterion score: **

Financial costs and benefits

Assuming the improvement in energy efficiency on the order of 10–15 percent as reported by boilers suppliers, replacing an old fuel oil-powered boiler could bring savings of around 35 000 litres of fuel oil per year. The associated investment is typically on the order of MAD 350 000 (or USD 35 000) for a 1 tonne of steam per hour boiler with a power capacity of 744 kW. The investment adds up to around MAD 500 000 (USD 50 000) for a turn-key installation. Maintenance costs are around USD 1 500 to 2 000 per year and a well-maintained boiler can last for 5 to 10 years. To assess the financial returns, the analysis considered:

- an economic life of 10 years
- an investment cost of USD 50 000 without any salvage value for the old boiler
- 35 000 litres of fuel oil savings per year
- no public subsidies for efficient boilers
- incremental maintenance costs of USD 1 000
- a market price of fuel oil of USD 0.45/litre

Financial returns

Under these assumptions, the financial IRR of water boiler refurbishment for a period of 10 years is on the order of 27 percent, and the payback time less than 5 years, which make the investment attractive. If there is a salvage value for the old boiler, the attractiveness of an investment on this climate technology improves further.

We can consider an alternative scenario based on the overall consumption reported by the HCP of 150 million litres of fuel oil for 2 000 total boilers in which:

- a boiler would consume 75 000 litres of fuel oil (150 million litres divided by 2 000 boilers)
- 9 375 litres of fuel oil savings per year (12.5 percent)
- an economic life of 15 years due to lower utilisation
- an investment cost of USD 50 000 without any salvage value for the old boiler

- no public subsidies for efficient boilers
- incremental maintenance costs of USD 500
- a market price of fuel oil of USD 0.45/litre

In this case the payback time for the investment would be around 14 years, yielding an IRR close to zero and a negative NPV for the same 12 percent discount rate used in the first scenario.

The results clearly show that the financial attractiveness of the technology will largely depend on how intensely used each boiler is. Still, the experience in other countries and the problems associated with combining data from different sources (in this case number of boilers and total aggregate consumption) suggest that the higher financial return is the most representative for the technology.

Mitigation cost

Criterion score: ***

The 35 000 litres of saved fuel oil correspond to a GHG emissions reduction of 101 tCO_2eq/year. Considering the same cost assumptions as for the financial analysis, but with a shadow price of fuel of USD 0.41/litre and an economic discount rate of 8 percent, the economic NPV is USD 4 170/year/boiler. Hence USD 41 could be saved per tCO_2eq of reduced emissions.

The estimates dramatically change for the second scenario described in the financial attractiveness analysis above. In this case, the mitigation would incur a cost of USD 70 per tCO_2eq. As discussed above, this second scenario is less likely and therefore all the graphs and conclusions of this report are based on a negative mitigation cost of USD -41 per tCO_2eq.

Data availability

Criterion score: *

Boilers used in the agrifood industry are registered with the Ministry of Energy. However, there is a number of them not covered by official statistics as they are imported into the country through unofficial channels. A registry of boiler used in the food industry should be available at the Ministry of Industry, however the project team did not manage to access it.

No official data could be found about the energy consumption (by energy carrier) for process heat in the agrifood industry or for process heat in general. Data from the HCP and information on capacity and consumption of the heat/steam generators were used to estimate energy consumption and associated GHG emissions. Potential for efficiency improvements, costs and number of boilers in use are based only on expert opinions.

Efficient cold storage

Table 36: Summary of the techno-economic criteria scoring for efficient cold storage in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
***	***	*	**	***	***	***	*

Source: Authors' compilation.

As mentioned before, this note focuses on energy efficiency measures to reduce electricity consumption of cold storage; and the chosen improvements for analysis can be summarised as follows:

- better part-load performance by installing VFDs to evaporators, compressors and condensers and repairing compressed air leakages;
- installation of fast doors with improved sealing;
- upgraded energy management and installation of LED lighting;
- improved warehouse wall insulation.

Quantifying storage capacity in Morocco and the potential for energy savings is not easy. GCCA data for 2014 points at 1.7 million m^3 (around 370 000 tonnes of food refrigerated), and 1.591 million m^3 for 2012. However, this seems to be based on outdated figures (IARW, 2014). An alternative source of data, Chemsi, reported in 2003 an estimated capacity of 1.7 million m^3 (or around 370 000 tonnes). According to an FAO expert consultation in 2011 (FAO, 2012b), this capacity increased by 55 000 tonnes just for horticultural products. On this basis, this note assumes a conservative total of 425 000 tonnes or 1.96 million m^3 [69] for the last year with data (2014). Table 37 clarifies these assumptions.

In terms of estimates on the potential to reduce GHG emissions, however, this only considers the ones installed before 2003, as those require the most improvements and therefore have the largest potential to reduce GHG emissions (1.7 million m^3).

69 Considering a storage need of 4.6 m^3 per tonne (EEAA, 2009).

Table 37: Cold storage capacity in Morocco as reported by GCCA and as assumed for this study

Year	GCCA reported capacity	National expert reports	Used in this report
		Million m^3	
2003	-	1.7	1.7
2010	-	1.96	
2012	1.591	-	
2014	1.7	-	1.96

Source: IARW, 2014; Chemsi, 2003; FAO, 2012b.

Technical assessment

Performance compared with international best practice

Criterion score: ***

Efficient cold storage equipment discussed here (VFD drives, LED lighting and sealed fast roll-up or sliding doors) is commonly available in Morocco. Table 38 provides examples of Moroccan companies with efficient cold storage.

Table 38: Industry-leading commercial companies using modern equipment in Morocco

Company name	Location	Subsector
Sapak (Koutoubia)	Mohammedia	Meat products
Eldin	HAD Doualem	Meat
Frigorifique Bouzerktoun	Casablanca	Seafood
Glacier ort	Casablanca (fishing port)	Ice for seafood industries
Le Bon Lait	Marrakech	Milk and derivatives
Tichka Frigo	Marrakech	Cold
Conserves Team	Mohammedia	Fish
La Maison du Foie Gras	Casablanca	Meats
Delta fish	Casablanca	Fish
Espadon conserves	Casablanca	Fish

Source: EEAA, 2009; authors' compilation.

Maturity of technical support services

Criterion score: ***

Maintenance services are widespread and the degree of technical knowledge is such that most operators can use the technology to its full potential.

Potential to reduce annual GHG emissions

Criterion score: *

There are two sources of GHG emissions attributable to cold storage. The direct one is the leakage of refrigerants. The phasing out of refrigerants is governed by the Montreal and Kyoto Protocols. The second and indirect source of emissions originates from energy spent for powering the cold storage facilities. This can be tackled either through energy efficiency improvement measures or the use of RE sources. In the present analysis, we only consider emissions from energy spent on powering cold storage units. Furthermore, as no analysis could be found recording the total energy use of Moroccan cold storages, an estimate was made based on the available data. The assumptions are the following:

- the average efficiency of Moroccan cold stores is close to 100 kWh/m^3 annually (based on the survey reported in MEDISCO, 2008);
- modern installations report electricity consumption below 50 kWh/m^3/year, in line with international best practice (the average of the European Union is 30–50 kWh/m^3 [European Commission, 2010]);
- the estimate of the potential emission reductions for Morocco is based on a number of analysed studied cases, described in the section on economic and financial attractiveness. For these cases, the average GHG emission reduction was 12.5 kWh/m^3;
- conversion from consumed energy to GHG emission was made using the grid electricity emission factor for Morocco of 0.73 $kgCO_2eq/kWh$, given that over 70 percent of emissions caused by refrigeration plants or cold warehouses are due to grid electricity consumption (FAO, 2012a).

Hence, with an annual average electricity consumption of 100 kWh/m^3 for cold warehouses installed before 2003, consumption is expected to be above 170 GWh annually, i.e. over 3 percent of the energy use in food processing (5 556 GWh as of 2013). Cold storage consumption of 170 GWh of electricity corresponds to around 120 $ktCO_2eq$ in emissions, representing around 6 percent of the total emissions of energy used in food processing (around 2 $MtCO_2eq$ in 2013), and less than 1 percent of the total emissions of agriculture and food processing in Morocco (FAOSTAT, 2015; IEA Statistics, 2015; HCP, 2015).

Given the models, of the roughly 16 thousand tonnes of the 120 $ktCO_2eq$ emitted could be reduced – accounting for less than 1 percent of the emissions of electricity used in food processing, and about 0.1 percent of the total agrifood emissions in Morocco.

Market assessment

Current technology adoption rate

Criterion score: **

The absolute current market uptake of the technology, i.e. the current volume of efficient storage, is given by the current estimated volume of cold storage (1.96 million m^3) deducted by the volume of cold storage installed before 2003 that would benefit from efficiency improvements (1.7 million m^3). This volume is 260 000 m^3 and represents 13 percent of the total industry capacity, a market uptake that still leaves considerable room for further deployment. Table 39 summarises the total existing capacity by products.

Table 39: Share of subsectors utilising Morocco's cold storage capacity

Product	Storage capacity (tonnes)	Share of total capacity (%)
Fruits and vegetables	300 000	66
Dairy products and derivatives	62 000	17
Fish	53 000	14
Meat	7 000	2
Ice	4 000	1
TOTAL	426 000	100

Source: EEAA, 2009 modified based on FAO, 2012b.

Trends in gap between current technology uptake and technical potential

Criterion score: ***

The demand for cold storage, especially of fruits and vegetables, is expected to increase sharply to meet the targets of the PMV. *Frigos de Marrakech*, the largest food warehouse in the region, cannot respond to all the demand it faces: reportedly it stores around 1 700 tonnes of fruit and vegetables per year while facing a demand for 2 000 tonnes per year (even considering that it has already increased its storage capacity from 900–1 000 tonnes per year in 2005 to 1 700 tonnes per year to date). Just in the Marrakech region, 5-10 percent of additional storage capacity is installed every year, which corresponds to one or two new food storage plants. According to the targets in the PMV, the country needs to increase its storage capacity by 2 million m^3 (430 000 tonnes of food refrigerated) in the coming years.

The volume of new and efficient storage facilities is increasing in the country. This means that today's significant gap between the volume of efficient and inefficient cold storage may shrink in relative terms. However, the number of cold storages suitable for efficiency improvements will expand as more plants gradually require refurbishment.

Economic assessment

Financial attractiveness

Criterion score: ***

Financial costs and benefits

The data used for the financial assessment were sourced from a number of case studies reported by the United Nations Industrial Development Organization (UNIDO) (2015a) in the framework of the regional MED-TEST programme and expert meetings during field work for this assessment (Table 40). The case studies considered were the following:

- *Boyauderie de l'Atlas* – Insulation of cold surfaces, regulation of pressure, limitation of chiller operation during peak hours, downloading of cold storage rooms to avoid exceeding the installed power, regulation of chiller condensers' evaporation temperature, improvement of the power factor, optimisation of the subscribed power, improvement of lighting, repair of compressed air leaks, reduction of compressors' idle operations, limitation of compressors' operation during peak hours, and installation of insulation valves on the air distribution network (investment: USD 33 625).
- *Fromagerie BEL* – Electrical power factor increase, optimisation of site lighting, installation of VFD on an air compressor, repair of compressed air leaks, and minimisation of compressors' idle operations (investment: USD 52 500).
- *Colainoord* – Setting of high and low pressure chillers, reduction of cold losses in cold pipes and room doors, and limitation of chillers' use during peak hours (investment: USD 2 500).
- *Conserverie des 2 mers* – Insulation of cold storage rooms (walls and ceiling), insulation of pipes, regulation of high and low pressure chillers, limitation of chiller operation during peak hours, unloading of cold storage in case of exceeding the installed power, increase in the capacity of the chillers' condensers, and reduction of the number of the chillers' compressors (investment: USD 26 550).
- *Cumarex* – Regulation high and low pressures of the chillers, insulation of cold distribution pipes and surfaces, limitation of the use of chillers during peak hours, door insulation, download of cold storage rooms in case of exceeding the installed power, installation of a heat recovery system on the chillers' condensers (investment: USD 10 000).

- *Frigos de Marrakech* – Equipped with around 300 kW nominal output cooling machinery for a storage capacity of around 20 000 tonnes of food. The facility uses ammonia as working gas and its walls are insulated using cork (as opposed to the more common polyurethane). The facility would significantly benefit from better insulation and, with a cost of around MAD 60 per linear metre, the plant manager estimated that electricity consumption could be lowered by around 15 percent.

The analysis also incorporates data from the following regional case studies:

- CLC, Tunisia – Improved efficiency of chillers
- Galina, Egypt – Preventive maintenance of motors
- EDFINA, Egypt – General retrofitting and installation of VFDs
- GIAS, Tunisia – Installation of VFDs

Table 40: Cost of emission reduction through cold storage energy efficiency measures in Morocco

Variable	Unit	Field data (Frigos de Marrakech)*	Average of UNIDO cases for Morocco	Average of UNIDO cases for the region
Investment cost	USD	470 000.0	25 035	58 391
Estimated capacity	tonnes	20 000.0	9 200	9 321
Storage bulk	m^3	92 000	42 320	42 874
Annual energy savings	kWh/year	234 000.0	478 600.0	816 750.0
Operational cost of the additional equipment	USD/year		750	1 750
Annual financial savings	USD	27 500	55 500	86 000
Average return on Investment	years	17	1.4	0.8
NPV	thousand USD/m^3	-285	350	586
Total avoided emissions	tCO^2/year	170	350	350
Mitigation cost	USD/year/ tCO_2eq	167	-100	-160
Financial IRR	%	1	>100	>100

Source: UNIDO, 2015a.

*Reported 300 kW power, 130–150 000 kWh monthly electricity, 240 000 USD investment with 15 percent energy savings.

Financial returns

Average results were produced for the three groups of data: *Frigos de Marrakech*, Moroccan case studies, and regional case studies. The analysis was made for:

- a 10 year time period and financial prices
- the average investment costs reported above
- annual financial savings estimated considering the country specific electricity emission factor and an assumed electricity price of USD 0.12 per kWh, an average obtained from the field visits

The cases studies from UNIDO documented the first selection of interventions on energy efficiency recommended by the Global Cold Chain Alliance. This probably explains the high financial returns and short returns on investment. On the other hand, the case of *Frigos de Marrakech* has different characteristics. The study's investment, aimed at substituting the cork insulation with polyurethane, is considerable with an estimated payback time of around 17 years. In this case, the financial results of such an investment would be negative.

The analysis shows that different measures result in varied energy efficiency gains and that no single standard retrofitting package can be advocated. This means that efficiency improvements in cold storage require preliminary energy audits in order to assess the current energy performance and potential for efficiency gains of the concerned facilities. It also means that some cases, such as that of *Frigos de Marrakech*, will not see investments in energy efficiency gains with the current policy framework. Nevertheless, the UNIDO case studies demonstrate that there are opportunities for significant energy savings with relatively small investments (from USD 10 000 to 52 000).

Another important consideration is that the FDA finances 10 percent of the investment cost, up to a maximum subsidy of USD 224 000, in the installation of cold storages for fruits and vegetables. Given that there is a strong demand for cold storage in Morocco, it is possible that with existing incentives, investing in new cold storage facilities instead of retrofitting old ones may yield more interesting NPVs. If that is the case, investment in new facilities will be given priority by investors over retrofitting.

Economic considerations

The financial analysis was made without accounting for any subsidies, as these are non-existent for retrofitting cold storage facilities. However, it is possible that in some cases, cold storage facilities contract individual electricity prices or use subsidised butane gas. Should this be the case, although the economic results of the investment would remain the same, the financial attractiveness of investments in energy efficiency gains would decrease.

Mitigation cost

Criterion score: ***

The cost associated with avoiding 1 tCO_2eq emissions per year varies between USD -200, i.e. a negative cost of mitigation, and USD 160, depending on the case. It seems that, while VFDs, fast doors with improved sealing, or LED lighting are attractive investments for energy efficiency, insulation improvement is not.

Data availability

Criterion score: *

Data available in the international literature regarding cold storage capacity is partial and might not provide a complete picture of the overall costs associated with energy efficiency gains. Reliable analyses on energy efficiency of warehouses in the country could not be found.

Biogas from manure and agri-residues

Table 42: Summary of the techno-economic criteria scoring for biogas from manure and agri-residues in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
**	*	**	***	***	*	*	**

Source: Authors' compilation.

This note focuses on commercial applications of biogas for power (heat and electricity), therefore small-scale (household size) or smallholder applications such as the ones promoted in Morocco in the past are not considered. Commercial applications of biogas are expected to be viable only above a certain size and in areas with high cow manure concentration and availability of agricultural residues, such as those close to a large farm or a number of small farms. According to local experts, it seems that commercial plants producing biogas for power from agricultural residues do not exist in Morocco, with only a few initiatives at trial phase[70].

70 See for example GreenWatt aiming at producing 30 MWh/ha/year from tomato residues - http://www.greenwatt.fr/fr/actualites/greenwatt-sinstalle-au-maroc.

Technical assessment

Performance compared with international best practice

Criterion score: **

Biogas production plants exist in Morocco but they do not use agri-residues as feedstock. There are mainly applications associated with wastewater treatment and landfill[71]. These are significantly different and more complex technologies from those applicable to agri-residues.

There are no local producers of medium- and large-scale industrial biogas plants in Morocco and it is likely that the technology would be imported from abroad. In fact, the best performing biogas plants to treat agri-residues are usually produced in Europe. There are local companies that are able to provide commercial biogas solutions developed together with a European technology partner using European technology[72].

Maturity of technical support services

Criterion score: *

As mentioned above, there is some biogas production in Morocco from municipal waste[73], therefore it can be stated that technical support services exist, although they are not widespread and would be insufficient to support the diffusion of the technology in the agrifood sector.

With respect to anaerobic fermentation from agri-residues at medium and large scales, technical support services do not exist and the degree of local technical knowledge is at a very early stage. The majority of operators do not know how to use the technology.

Potential to reduce annual GHG emissions

Criterion score: **

An updated and thorough assessment of the amount of agri-residues available in the country could not be found. The analysis done here is based on a simple

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71 For example, since 2015 the municipality of Fez uses landfill biogas to produce electricity for public lighting. With an installed power of 1.12 MW, the project has been implemented by the American company Ecomed who invested around USD 10 million in partnership with other public actors, and is expecting returns for over USD 800 thousand in 2016 - http://www.usinenouvelle.com/article/maroc-fes-s-eclaire-au-biogaz-en-valorisant-ses-dechets.N341173.

72 See for example Generizon: http://generizon.com/en/generizon-vision-2/.

73 The biogas plants at major cities are using wastewater sludge as feedstock. For example, the Marrakech wastewater treatment plant has an output of 18 000 m^3 biogas/day and an energy production capacity of 1.8 MW_{el}. In Fez, with 28 800 m^3 of biogas /day the energy production capacity is 3.2 MW_{el} (Waterleau, 2014).

assessment undertaken by the *Agence nationale pour le développement des énergies renouvelables et l'efficacité énergétique* **(**National Agency for the Development of Renewable Energy and Energy Efficiency [ADEREE]) (ADEREE, 2011) of the technical potential for biogas production from wastage, based on data for 2010 and with projections for 2020. Two sources of feedstock from agriculture were studied: horticultural residues and cattle manure. Cereal residues, despite being a suitable substrate for biogas production, were not considered since they are more suitable for direct combustion. The analysis assumes that no GHG emissions due to land use change occur since biogas is expected to be produced from existing agricultural residues. In addition, the following parameters and assumptions were taken into consideration in the analysis:

For horticulture residues:

- horticulture crop residues have high moisture content (usually greater than 90 percent according to the literature[74]) making them suitable for biogas production;
- in 2010, the harvested surface of horticulture crops was 267 thousand hectares;
- projections for 2020 harvested area are 500 thousand ha, in line with the expansion of surface used for horticulture crops forecasted for the PMV;
- the scenario for 2015 (by the authors) corresponds to the average surface under horticulture crops between 2010 and 2020s, i.e. 383 thousand hectares;
- the average horticulture (residue) production is 20 tonnes/ha;
- the biogas yield is 60 m^3 of biogas/tonne of fresh matter (this is a conservative estimate since data on horticultural residues from the CropGEN database show possible biogas yields above 80 m^3 biogas/tonne of fresh matter);
- the calorific value (LHV) of biogas is 6 kWh/m^3;
- the efficiency conversion factor for electricity production is 35 percent;
- The emission factor is 0.802 $kgCO_2eq/kWh$, above the grid electricity factor of 0.729 $kgCO_2eq/kWh$ for 2013 considered throughout this study.

The results obtained from these assumptions are summarised in Table 43.

74 See for instance Pandey et al., 2015.

Table 43: Total electricity potentially generated and GHG emissions savings from biogas using horticultural residues as feedstock, 2010 estimates and 2015/2020 projections

Year	Harvested surface (ha)	Residues quantity (thousand t/year)	Total biogas produced (thousand m^3)	Total technical electricity potential (MWh/year)	GHG emission savings (thousand tCO_2eq /year)
2010	267 000	5 340	320 400	672 840	529
2015	383 767	7 675	460 520	967 093	760
2020	500 534	10 011	600 640	1 261 346	991

Source: Adapted from ADEREE, 2011.

Note: Considering the grid emission factor for 2013 used in throughout this study, the GHG emissions savings potential would be 705 thousand tCO_2eq /year.

For cattle manure:

- Cattle is considered the only suitable source of feedstock for biogas production amongst livestock systems in Morocco, because: (i) local sheep and goats normally graze extensively therefore their manure is inaccessible (confined feeding operations usually produce recoverable manure as opposed to open range farming); and (ii) poultry manure needs a pre-treatment before being suitable as a substrate for biogas. In addition, according to ADEREE no reliable data are yet available on biogas yields from poultry manure[75] in Morocco.
- In 2010 there were about 2.6 million cattle LUs in the country.
- The projection for the cattle population in 2020 is 16.8 million units (a dramatic increase likely due to a shift in production systems).
- The scenario for 2015 (by the authors) corresponds to the previous sections that estimated 3.2 million heads.
- Only a small number of farms has both sufficient size and a production system that allows manure collection in a viable way; it is estimated that only 5 percent of the total cattle LUs are on these farms (no additional detail is provided by ADEREE on the size of such farms). Under this assumption, for 2010, only a population of just 132 560 LUs out of a total of 2.6 million (in 2010) could be considered in the estimate of the technical energy potential of biogas from cattle manure (both liquid and solid) in Morocco.

75 Poultry manure or chicken dung can easily be used for biogas production, and the best way to use it is in co-fermentation with cattle manure. The only pre-treatment that needs to be undertaken is related to egg laying chicken, whose manure might need sedimentation of residues in water before being used as biogas feedstock.

- The share of animals in kept in stables is maintained throughout the years (probably a conservative assumption should production systems change over time).
- Each cattle LU can generate 1 m^3 manure/day.
- The percentage of accessible/recoverable manure is represented by the percentage of days in which animals are kept in stables over the year. More specifically, it is considered by ADEREE that cattle are kept some 215 days in stable, or about 60 percent of the time[76].
- The LHV of biogas is 6 kWh/m^3.
- The efficiency conversion factor for electricity production is 35 percent.
- The emission factor is 0.786 kgCO_2eq/kWh, slightly above the grid electricity factor of 0.729 kgCO_2eq/kWh for 2013 considered throughout this study.

The results obtained from these assumptions are summarised in Table 44.

Table 44: Total electricity potentially generated and GHG emissions savings from biogas using cattle manure as feedstock, 2010 and 2015/2020 projections

Year	Number of heads (thousands)	LU with potential (5% of cattle population (thousands)	Total biogas produced (thousand m^3/year)	Total technical electricity potential (MWh/year)	GHG emission savings (thousand tCO_2eq /year)
2010	2 651	133	28 498	59 846	48
2015	3 200	160	34 400	72 240	57
2020	16 800	840	180 600	379 260	303

Source: Adapted from ADEREE, 2011.

Note: Considering the grid emission factor for 2013 used in throughout this study, the GHG emissions savings potential would be 53 thousand tCO_2eq/year.

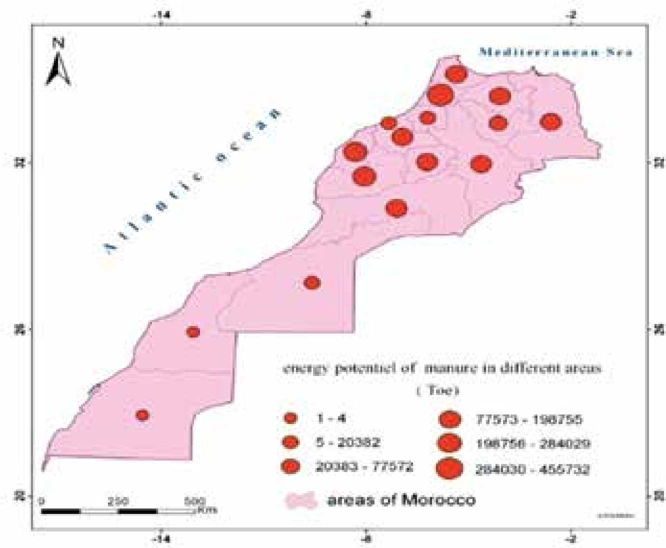
The combined results for horticultural residues and manure are, for 2010, a technical electricity production potential of 730 GWh and GHG emission reduction potential of 570 thousand tCO_2eq per year. The authors' estimates for 2015 result in a technical electricity production potential of 1 040 GWh and GHG emission reduction potential of 817 thousand tCO_2eq/year (about 3.5 percent of the total emissions of the agrifood sector). Using the grid emission factor for 2013, the emission reduction potential would be 757 thousand tCO_2eq/year.

76 Other studies (see for instance Runge et al., 2011) have reported this figure as being a good representative average for dairy and meat cattle in the country (according to local experts, meat cattle in intensive production systems are generally kept more time in stables compared to dairy cattle, due to the fact that they are fed and raised more intensively to grow faster; as a consequence, accessibility of manure is higher in meat cattle production systems than in dairy).

In line with the data above, a technical potential of 21 PJ was estimated recently by the CDER (National Centre on Renewable Energies). This corresponds to a biogas potential from animal excrements, the food industry, the municipal solid waste and wastewater they estimate of 1 million m^3 of biogas per year as of today. Furthermore, a potential of around 1 TWh/year from agro-industrial residues (18.9 PJ) is reported by GIZ, 2012 (Wauthelet, 2012), and 8.6 PJ just from crop residues (also in line with the ADEREE estimate reported above).

Figure 31 reports information on the geographical distribution of manure that could potentially be used for biogas production.

Figure 31: Biogas energy potential from manure in Morocco



Source: Afilal et al., 2013.

Market assessment

Current technology adoption rate

Criterion score: ***

The market of biogas technology and its adoption as a climate technology could be measured using the share of agricultural residues currently used as biogas feedstock or, alternatively, the amount of cubic meters of biogas and therefore the share of associated energy produced. However, no commercial operation of biogas production from agri-residues could be found as further confirmed by the MEM. Only feasibility studies with implementation were reported, including from Elephant Vert, the largest company treating organic waste in the country. These means that the size of the remaining market share is therefore very large and corresponds roughly to the total potential for use of agricultural residues.

Trends in gap between current technology uptake and technical potential

Criterion score: ***

With expanding agricultural production, the amount of agricultural residues that could potentially be used for biogas also increase. According to the estimates for horticultural residues and manure reported in Table 43 and Table 44, the amount of residue should increase by 88 percent and 633 percent, respectively, between 2010 and 2020. In fact, as reported by FAOSTAT, the Moroccan agriculture production is on the rise and increased by 86 percent as a whole (Agriculture PIN) between 2000 and 2013. The production of biogas from residues over the same period is negligible. Therefore, the gap is large and has been increasing in recent times.

Economic assessment

Financial attractiveness

Criterion score: *

Financial costs and benefits

The biogas production potential of different residues can vary significantly. For example, from 1 tonne of cattle manure (20–25 percent dry manure), it is possible to generate around 180 kWh of electricity; from 1 tonne of cattle liquid effluent around 40 kWh; from 1 tonne of orange pulp up to 13 kWh; from 1 tonne of blood up to 8 kWh; from 1 tonne of chicken manure around 18 kWh, etc. Therefore, the financial analysis results will vary depending on the agri-residue available and its cost (at least a transport and storage cost should be considered for the residues, which are often acquired at no cost).

Globally, anaerobic digester power systems (not only from residues) have capital costs between USD 500 and USD 6 100/kW (REN21, 2015) while global levelised costs of energy ranged between USD 0.06 and USD 0.15/kWh in 2012 (IRENA, 2013). Hence, the examples used in this analysis should be considered indicative of the financial attractiveness of biogas production in Morocco and not representative of all available options.

Assuming European standard compliant technology is used, four types of plants were modelled: 250 kW, 600 kW, 1 200 kW and 1 500 kW. Table 45 summarises the parameters that were used in the analysis. The costs in Table 45 are for plants operating 300 days per year producing biogas and digestate from dairy cattle manure. Major assumptions in the models that are not explicit in the table are as follows:

- feedstock is available free of charge at collection point (pits in dairy farms);
- unit feedstock transportation costs increase with distance from the collection point; distance increases with the size of the plant (as given the small average size of Moroccan farms, feedstock for large plants might have to be collected from several farms at considerable distances);
- unit feedstock transport costs and storage costs are based on data from similar projects in the region;
- investment costs are within ranges verified in other countries and are assumed to apply to Morocco as most equipment is imported;
- skilled and unskilled labour costs are those usually verified in rural areas in Morocco (field data);
- water is free of charge, the only implied costs being the energy to pump it;
- feedstock needs are a function of the capacity of the plant and average temperature throughout the year, based on assumptions that dairy cattle manure has 29 percent total solids, of which 55 percent are volatile solids, a biomethane potential of 258 m^3 CH_4/tonne volatile solids and a volume of methane of 60 percent;
- water, heat, NaOH, and energy requirements are a function of feedstock quantities based on standard coefficients;
- the calorific value of the biogas is 6 kWh/m^3;
- the efficiency conversion to electricity is 35 percent.

Table 45: Major cost assumptions used in the four models for biogas plants

			Capacities (kWe)			
			250		600	
			Operating hours per year	7,200	Operating hours per year	7,200

Inputs	Unit	Unit Price (USD/Unit)	Quantity (Unit/year)	Total (USD/year)	Quantity (Unit/year)	Total (USD/year)
Single Feedstock	t	$0.00	13,103	$ -	31,448	$ -
Water Make-Up	m^3	$0.00	4,288	$ -	10,292	$ -
Electricity -Consumption Self-Supplied	KWh	$ 0.00	125,551	$ -	301,322	$ -
Heat	GJ	$3.29	2,934	$ 9,653	7,042	$ 23,168
NaOH	t	$ 25.00	131	$ 3,276	314	$ 7,862
Subtotal				*$ 12,929*		*$ 31,030*

Labour and miscellaneous costs	Unit	Unit Price (USD/person-hour)	Quantity Unit (operating hours above)	Total (USD/year)	Quantity Unit (operating hours above)	Total (USD/year)
Unskilled labour	# employee	$1.20	1	$ 8,640	2	$ 17,280
Skilled labour	# employee	$7.00	1	$ 50,400	1	$ 50,400
Miscellaneous costs			20%	$ 11,808	20%	$ 13,536
Subtotal				*$ 70,848*		*$ 81,216*

Transportation	Unit	Unit Price (USD/t/km)	Quantity Unit (tons from above)	Total (USD/year)	Quantity Unit (tons from above)	Total (USD/year)
Feedstock 1 - Dairy Cattle	km	$0.15	5	$ 9,827	20	$ 94,343
Subtotal				*$ 9,827*		*$ 94,343*

Storage	Unit	Unit Price	Quantity (unit/year)	Total (USD/year)	Quantity (Unit/year)	Total (USD/year)
Feedstock 1 - Dairy Cattle	t	$0.33	1,529	$ 504	3,660	$ 1,211
Biogas Low-pressure system	m^3	$0.01	100,000	$ 1,000	240,000	$ 2,400
Subtotal				*$ 1,504*		*$ 3,611*

Investment	Unit	Years	Total USD (year 1)	Depreciation (USD/year)	Total USD (year 1)	Depreciation (USD/year)
Equipments	USD	20	$ 755,721	$ 37,786	$ 1,743,455	$ 87,173
Building	USD	20	$ 174,511	$ 8,726	$ 387,093	$ 19,355
Installation Distribution and/or Upgrac	USD	20	$ 129,618	$ 6,481	$ 287,513	$ 14,376
Total investments			*$ 1,059,850*		*$ 2,418,061*	
			Total Depreciation	*$ 52,993*	Total Depreciation	*$ 120,903*
Maintenance cost		20%		$ 10,598.50		$ 24,180.61
Subtotal			*$*	*63,591*	*$*	*145,084*

Other costs	Unit	Rate (%)		Total (USD/year)		Total (USD/year)
Plant overhead	USD	5%		$ 3,482		$ 4,593
General and administrative cost	USD	10%		$ 9,786		$ 14,102
Subtotal				*$ 13,268*		*$ 18,695*

Total costs	Total (USD/year)	Share (%)	Total (USD/year)	Share (%)
Total operating costs	*$ 95,109*	*55%*	*$ 207,799*	*56%*
Total fixed costs	*$ 63,591*	*37%*	*$ 145,084*	*39%*
Total other costs	*$ 13,268*	*8%*	*$ 18,695*	*5%*
Total production costs	*$*	*171,968*	*$*	*371,578*

			Capacities (kWe)			
			1,200		1,500	
			Operating hours per year	7,200	Operating hours per year	7,200
Inputs	**Unit**	**Unit Price (USD/Unit)**	**Quantity (Unit/year)**	**Total (USD/year)**	**Quantity (Unit/year)**	**Total (USD/year)**
Single Feedstock	t	$0.00	62,895	$ -	78,619	$ -
Water Make-Up	m^3	$0.00	20,584	$ -	25,730	$ -
Electricity – Consumption Self-Supplied	KWh	$ 0.00	602,643	$ -	753,304	$ -
Heat	GJ	$3.29	14,084	$ 46,336	17,605	$ 57,920
NaOH	t	$ 25.00	629	$ 15,724	786	$ 19,655
Subtotal				*$ 62,059*		*$ 77,574*
Labour and miscellaneous costs	**Unit**	**Unit Price (USD/person-hour)**	**Quantity Unit (operating hours above)**	**Total (USD/year)**	**Quantity Unit (operating hours above)**	**Total (USD/year)**
Unskilled labour	# employee	$1.20	4	$ 34,560	5	$ 43,200
Skilled labour	# employee	$7.00	1	$ 50,400	1	$ 50,400
Miscellaneous costs			20%	$ 16,992	20%	$ 18,720
Subtotal				*$ 101,952*		*$ 112,320*
Transportation	**Unit**	**Unit Price (USD/t/km)**	**Quantity Unit (tons from above)**	**Total (USD/year)**	**Quantity Unit (tons from above)**	**Total (USD/year)**
Feedstock 1 - Dairy Cattle	km	$0.15	30	$ 283,028	40	$ 471,714
Subtotal			*$*	*283,028*	*$*	*471,714*
Storage	**Unit**	**Unit Price**	**Quantity (Unit/year)**	**Total (USD/year)**	**Quantity (Unit/year)**	**Total (USD/year)**
Feedstock 1 - Dairy Cattle	t	$0.33	6,421	$ 2,119	9,172	$ 3,027
Biogas Low-pressure system	m^3	$0.01	420,000	$ 4,200	600,000	$ 6,000
Subtotal			*$*	*6,319*	*$*	*9,027*
Investment	**Unit**	**Years**	**Total USD (year 1)**	**Depreciation (USD/year)**	**Total USD (year 1)**	**Depreciation (USD/year)**
Equipments	USD	20	$ 2,955,147	$ 147,757	$ 4,037,656	$ 201,883
Building	USD	20	$ 644,140	$ 32,207	$ 891,130	$ 44,557
Installation Distribution and/or Upgrac	USD	20	$ 480,404	$ 24,020	$ 661,887	$ 33,094
Total investments			*$ 4,079,691*		*$ 5,590,673*	
			Total Depreciation	*$ 203,985*	Total Depreciation	*279,534*
Maintenance cost		20%		$ 40,796.91		$ 55,906.73
Subtotal			*$*	*244,781*	*$*	*335,440*
Other costs	**Unit**	**Rate (%)**		**Total (USD/year)**		**Total (USD/year)**
Plant overhead	USD	5%		$ 6,288		$ 7,475
General and administrative cost	USD	10%		$ 21,110		$ 25,328
Subtotal			*$*	*27,397*	*$*	*32,803*
Total costs			**Total (USD/year)**	**Share (%)**	**Total (USD/year)**	**Share (%)**
Total operating costs			*$ 449,159*	*62%*	*$ 664,635*	*64%*
Total fixed costs			*$ 244,781*	*34%*	*$ 335,440*	*32%*
Total other costs			*$ 27,397*	*4%*	*$ 32,803*	*3%*
Total production costs			*$*	*721,338*	*$*	*1,032,879*

Source: Based on authors' calculations.

Financial returns

The only source of income was the electricity sold to the grid at a price of USD 0.11/kWh. The analysis does not consider the co-benefit of the produced digestate. Digestate can substitute fertiliser (if a local application is foreseen) or be sold, should a market for this product exist. Twenty years' cash flows were built for each of the plants for the above models. NPV was estimated for a discount rate of 12 percent. The results are shown in Table 46.

Table 46: Financial returns for the four models for biogas plants

Energy Balance	Unit	Capacities (kWe)			
		250	600	1,200	1,500
Electricity Production	kWh/year	1,800,000	4,320,000	8,640,000	10,800,000
Electricity Consumption (water pre-treatment, agitation, water pumping)	kWh/year	-125,551	-301,322	-602,643	-753,304
Electricity Available for Selling	kWh/year	1,674,449	4,018,678	8,037,357	10,046,696

Financial Results	Unit	(Unit/year)			
		250	600	1,200	1,500
IRR	%	2.1%	4.7%	6.2%	2.1%
NPV	USD	($571,130)	($1,005,196)	($1,371,275)	($3,004,572)
Herd size for 35kg of recoverable manure per LU per day	LU	1,741	4,179	8,358	10,448

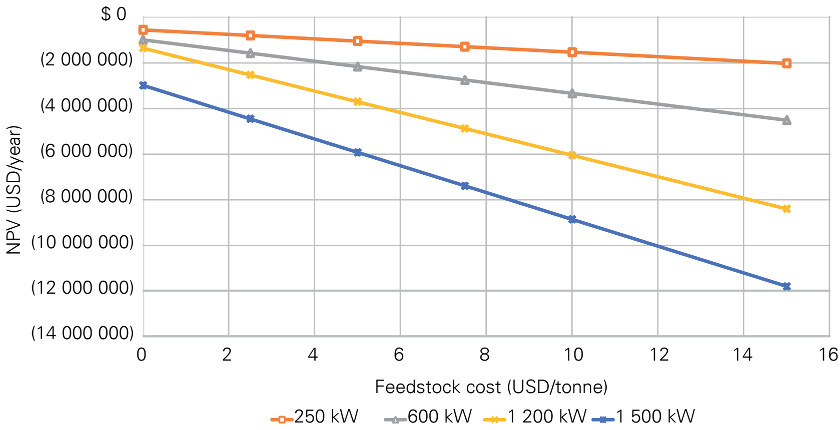
Source: Based on authors' calculations.

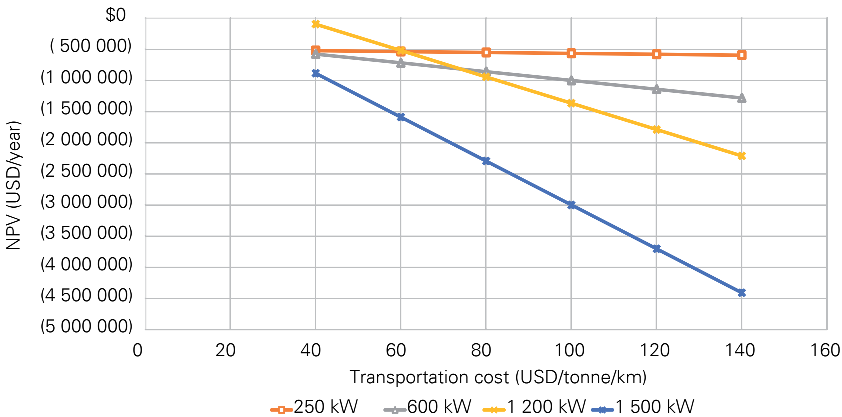
Given the current average electricity price of USD 0.11/kWh, biogas plants in Morocco are not expected to provide interesting financial returns to investors. The 600 kWe and 1 200 kWe plants show slightly more promising results than those of 250 kWe, but they significantly depend on feedstock transport costs (see sensitivity analysis below). Considering that for a herd of dairy cows producing an average 35 kg of fresh manure per day during the 215 days in which they are in stable, a plant with the capacity of 600 kWe would require 4 180 cows to operate. Given Morocco's farm size characteristics, such a plant would probably imply considerable transport costs to collect manure from dispersed farms. In fact, the 250 kWe plant is the most easily adapted model to the Moroccan reality.

A sensitivity analysis was conducted on the following variables: feedstock, water, labour, transport and investment costs. Different scenarios for a hypothetical use of the digestate were also considered, assuming savings from fertiliser substitution ranging from USD 0 to 10 per tonne. Figure 32 summarises the results of the variables for which the models showed greater sensitivity.

The models are very sensitive to feedstock, transport and investment cost. Nevertheless, it is clear that when these variables are within realistic ranges, biogas is not a financially viable energy generation option in Morocco, even considering the benefits from digestate use. Although not modelled, financial returns could improve significantly if a local use for the co-generated heat could be found, for example process heat, drying food or ambient or greenhouse heating.

Figure 32: Results from the sensitivity analysis for feedstock, transportation and investment costs and digestate market price





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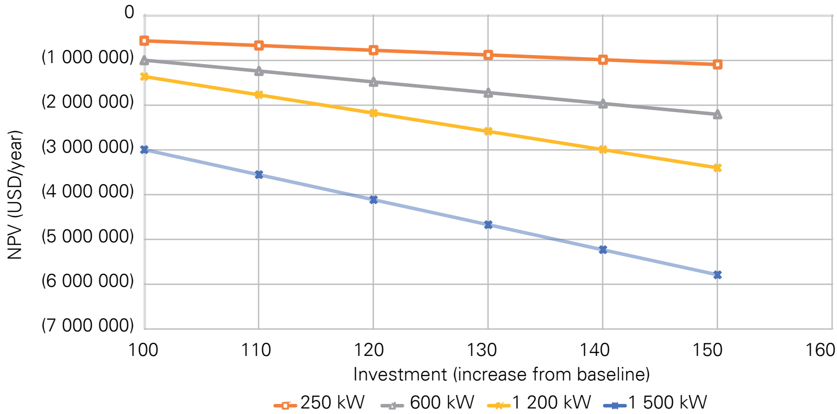
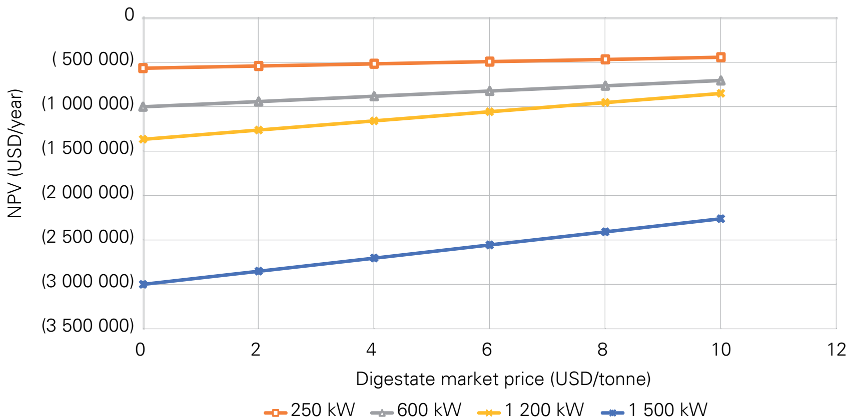




Source: Authors' calculations.

Mitigation cost

Criterion score: *

No incentives exist for biogas production from residues in Morocco and the economic results were deemed to be the same as the financial results presented above. Considering the 2013 national electricity emission factor (see Annex), an economic discount rate of 8 percent and no or negligible economic benefits due to digestate use, the mitigation cost obtained for the 250 kWe capacity plant is USD 17/tCO_2eq. More interesting results could be obtained with other assumptions; for example, that the residues are available free of charge. In this case, the mitigation cost of this technology would be just USD 13/tCO_2eq.

Data availability

Criterion score: **

Data on biogas production should be available at the MEM as well at the ADEREE. After discussing with local experts including experts from the Ministry of Environment, it was concluded that no commercial experiences producing power from agri-residues through anaerobic digestion exist in the country.

Technical information about the cost of biogas production from residues on a commercial scale is not available, although pilot trials have been ongoing. This kind of information could only be collected through interview and surveys of operators on an ad hoc basis and therefore could not be used for this assessment.

Renewable energy systems

Table 47: Summary of the techno-economic criteria scoring for renewable energy systems in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
***	***	**	***	**	*	**	**

Source: Authors' compilation.

As illustrated in Table 4, this climate technology is in fact a group of technologies: (i) PV and wind installations potentially serving farms and agribusinesses and that are connected to the national grid; and (ii) solar water heaters providing hot water for on-farm or food industry operations such as cleaning/sanitation and/or pasteurisation in food processing. The focus is on on-grid RE applications satisfying energy needs of farms or agribusinesses.

Since most criteria assessed here apply not just to the agrifood sector but to all sectors, and RE is not necessarily produced and consumed within the same sector, a country-wide approach to the techno-economic assessment of these systems has been adopted.

Technical assessment

Performance compared with international best practice

Criterion score: ***

PV systems and wind turbines are technologies for which no substantial performance differences exist among countries, since the vast majority of equipment is imported from a few manufacturing countries. Solar water heaters on the contrary are often locally manufactured. For flat collectors (the most common systems), the technology is quite standard so that no big performance differences exist between Morocco and other countries. Vacuum tube solar collectors are not common in Morocco. With reference to solar water heaters, integral collector systems (or ICS, where the water tank is integrated with the collector) represent the state of the art technology in most of the world except for northwestern European countries (where thermosiphon or pumped systems are state of the art). ICS usually perform worse than thermosiphon, and worse when compared with pumped systems, but such differences are small in sunny regions. Efficient thermosiphon systems are largely available in Morocco, while pumped systems are less common.

Maturity of technical support services

Criterion score: ***

Currently, according to the MEM (2012), Morocco is ready to produce RE equipment, such as: (i) components of wind turbines (pales, mats, generators, transformers, etc.); (ii) components of PV plants (cells, strata, slides, panels, supports, etc.). Most of this equipment is imported at the moment. On the other hand, many of the solar water heating (SWH) systems are manufactured in the region[77] (AFED, 2013).

On the basis of discussions held with local experts as well as with a number of enterprises active in RE and part of the *Confederation Générale des Entreprises du Maroc* (CGEM), technical support services for renewables are widespread and the degree of technical knowledge is such that most operators can use the technology to its full potential.

Potential to reduce annual GHG emissions

Criterion score: **

Morocco generated about 3 300 GWh of RE in 2014 (ONEE, 2015). The solar energy programme for 2020, aiming for a capacity of 2 000 MW and an

77 It is interesting to note that installation costs for such systems account for about one-half of total capital costs accrued to local businesses and employees (AFED, 2013).

annual production of 4 500 GWh, would further reduce GHG emission by 3.7 million tonnes of CO_2 per year. Similarly, if the wind energy programme meets its target of 2 000 MW and an annual production of 6 600 GWh, it would reduce an additional 5.6 million tonnes of CO_2 per year (MEM, 2012a). Part of the RE potential (and the associated GHG savings) can be generated and consumed within or outside the agrifood sector (no sector-specific statistics exist as already mentioned in Step 1).

RE has the potential to reduce all fossil fuel-related GHG emissions of the agrifood sector (ranging from 4.6 to over 10 $MtCO_2eq$, depending on the data source). PV and wind power have the combined potential to reduce all of the GHG emissions associated with electricity used in agrifood[78] (1.5 Mt CO_2eq in 2012/2013 on the basis of IEA and MEM data) while for solar heaters the potential is significantly lower. In fact, most process heat is needed at very high temperatures, which solar heaters cannot provide. Assuming that only 10 percent of process heat used in agriculture and the food industry could be met by solar heaters, a potential saving of over 0.3 $MtCO_2eq$[79] can be expected (calculated on the basis of national accounts for energy and MEM statistics).

Therefore, the technical potential for the three technologies considered is at least 1.8 $MtCO_2eq$ (around 7.7 percent of total GHG emission of the agrifood sector). This number is probably higher in reality since, as mentioned in Step 1, the energy GHG emissions of the agrifood sector considered in this study, and in particular the food industry emissions, are likely underestimated.

Market assessment

Current technology adoption rate

Criterion score: *

In Morocco, the national electricity grid has a high penetration rate even in rural areas, and most of the agrifood industry is connected to the national grid. Additionally, no data exist on RE installations to serve specifically agrifood sector enterprises – even if they are backed up by and/or feeding the national grid. Hence, the technology adoption rate needs to be generic and not specific to the sector under study.

78 PV and wind generation produce electricity, they are therefore assumed to be able to displace electricity generation from other sources (and related GHG emissions). The GHG emissions avoided by replacing electricity used in agrifood with renewables directly depends on the country emission factor for electricity generation, which is the same for all sectors, and can change over time. The country emission factors for grid electricity used in this document are reported in the Annex and have been calculated by the IEA.

79 Process heat emissions in the food industry and agriculture total around 3 $MtCO_2eq$ approximately split as follows: 0.3 $MtCO_2eq$ from LPG, 0.82 Mt from fuel and 1.5 Mt related to the use of electricity. Diesel and gasoline are assumed not to be used for process heat.

As to overall national adoption of RE technologies, according to the *Office National de l'Électricité et de l'Eau Potable* (ONEE), in 2014 the total electricity production in Morocco reached almost 30 000 GWh, most of which (47 percent) was generated through coal-powered plants. According to the same data source, RE accounted for about 11 percent of total production in 2014 (3 300 GWh).

IRENA reports that in 2014 Morocco had a total installed RE production capacity of 2 598 MW. Of this, solar PV installed capacity accounted for just 0.6 percent – 17 MW – and installed wind power capacity for around 30 percent, or 787 MW (IEA, 2014). The remaining RE installed capacity is in hydropower. Unfortunately, these figures are aggregated across all sectors and the present report could not rely on specific numbers for the agrifood sector (e.g. RE power installed and used on-farm). Still, overall use of PV, solar heaters, and wind turbines in the agrifood sector is minor at present.

With regards to solar water heaters, the *Programme de Développement du Marché Marocain des Chauffe-eau Solaires* (PROMASOL) promotional scheme (REN21, 2013 – see also Step 4) led Morocco to a SWH installed capacity of 245 MW and a total collection area of 350 000 m^2 in 2012. The adoption of SWH is still marginal however and relatively few innovators have adopted the technology.

Trends in gap between current technology uptake and technical potential

Criterion score: **

IRENA (2015a) data show that Moroccan total RE installed capacity has increased by almost 50 percent in just 7 years from 1 795 in 2007 to 2 598 MW in 2014. Specifically, wind power capacity has been increasing very rapidly, showing a more than tenfold increase from just 64 MW in 2006 to 787 MW in 2014 (Table 48) while PV increased from 11 MW to 17 MW (+55 percent) during the same period. Most importantly, the recent regulatory/legal developments related to RE are expected to accelerate the uptake of small and medium PV systems across sectors. In particular, the changes relate to allowing surplus electricity generated from renewable sources to be fed into the national grid at a low voltage (up to 20 percent of total renewable electricity generation). IEA statistics also show a noticeable increase of 151 percent in RE production in the period 2006–2013 (from 1 784 GWh to 4 471 GWh) while the total energy production increased by 34 percent (from 10 814 ktoe to 14 530 ktoe) over the same period.

Table 48: RE installed capacity and energy production growth in Morocco, 2006–2014

	2006	2007	2008	2009	2010	2011	2012	2013	2014	% growth 2006–2014
Installed capacity (MW)										
Total RE	1 795	1 857	1 863	1 992	2 090	2 095	2 097	2 294	2 598	45
Wind	64	124	124	253	286	291	291	487	787	1 130
Solar PV	11	12	13	13	14	14	15	16	17	55
Hydropower	1 721	1 721	1 726	1 726	1 770	1 770	1 770	1 770	1 770	3
Energy production (GWh)										
Total RE	1 784	1 610	1 671	3 343	4 290	2 831	2 544	4 471	n.a.	151
Wind	183	279	298	391	659	692	728	1 841	n.a.	906
Solar PV									n/a	
Hydropower	1 601	1 331	1 373	2 952	3 631	2 139	1 816	2 990	n.a.	87

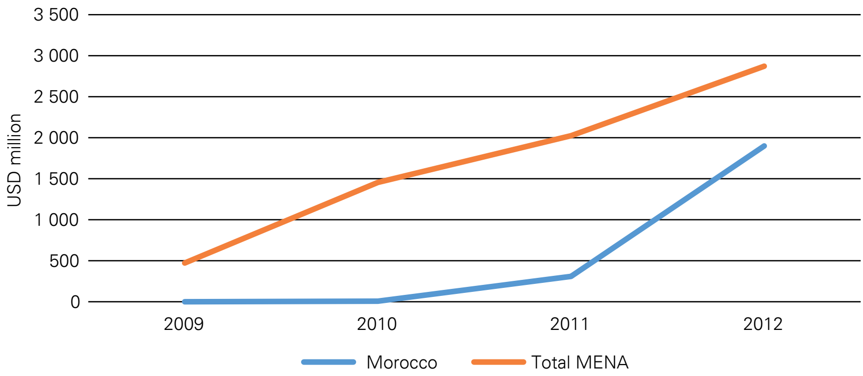
Source: Data on installed capacity are from IRENA, 2015a; data on energy production are from IEA/IRENA Joint Policies and Measures database, 2015.

According to IEA, overall electricity consumption increased from 19.2 TWh in 2006 to 28.4 TWh in 2014 while PV and wind electricity generation increased from 0.3 TWh to above 0.8 TWh (MEM, 2016). The share of renewable electricity from PV and wind over electricity has been increasing considerably but is still small in absolute terms.

As already mentioned, in terms of RE targets, Morocco aims to achieve 42 percent of RE capacity by 2020 (including hydropower), and 52 percent by 2030. In particular, Morocco aims to increase installed renewable capacity by 2 GW of solar, 2 GW of wind and 2 GW of hydropower. IRENA estimates that as much as 3.2 GW of new capacity is economically achievable just for wind by 2020. The bulk of RE installation already is in the pipeline stage (IFC, 2013), which means the gap between renewable and total energy production is still significant but should continue to close fast.

SWH capacity also increased over the past few years (mainly as a consequence of the PROMASOL programme), with a one-third increase from 231 thousand m^2 of collectors in 2008 to 450 thousand m^2 in 2014 (SHC, 2016). In monetary terms, investments in renewable energy technologies have been growing remarkably in recent years (REN21, 2013) (Figure 33).

Figure 33: New investment in RE by Morocco and MENA countries, 2009–2012

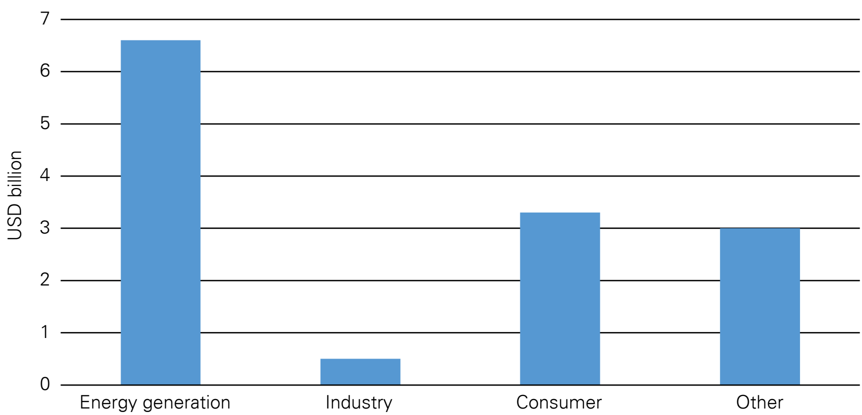


Source: REN21, 2013.

Note: MENA includes Algeria, Djibouti, Egypt, Iran, Iraq, Israel, Libya, Morocco, Palestinian Territories, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, and Yemen.

Overall, IFC estimates that potential investment in energy generation and transmission account for more than USD 6 billion, almost all in renewables (Figure 34). Moreover, IFC (2013) estimates that the commercially viable investment potential for RET by 2020 is over USD 3 billion for wind power and USD 800 million for PV. These are significant investments in renewables which contribute to closing the market gap between total energy and RE generation.

Figure 34: Investment potential for key RE technologies in Morocco by 2020



Source: Adapted from IFC, 2013.

Economic assessment

Financial attractiveness

Criterion score: *

Financial costs and benefits

This section provides a rapid and simple analysis of the systems considered in this note: PV, SWH and wind turbines. For a given investment cost and electricity production capacity and considering the electricity costs in Morocco, an IRR calculated over 10 years is estimated. The analysis, in the case of PV and wind turbines, is made for systems that are connected to the grid, would not require back-up batteries and would sell any energy surplus back to the grid at the same price as it was bought, i.e. systems for which all produced energy is used either to offset energy costs or to generate energy sales.

Financial returns

For PV, a simple analysis to illustrate potential returns was conducted assuming (i) a turnkey price for a PV system of USD 1 500/kWp[80]; (ii) annual electricity generated by a 1 kWp system of 1 700 kWh[81]; and (iii) an average price of electricity of USD 0.11/KWh. This results in savings on the electricity bill of USD 200/year/installed kWp. In such a situation, the IRR would be 7 percent. The results are naturally quite sensitive to changes in the electricity price. At a price of USD 0.15/kWh (the electricity price at peak period), the IRR would be 11 percent.

For SWH, an example by Zein (2014) estimates that 2 m^2 of ICS collectors with a water capacity of 160 litres would have a retail sales price of about USD 400 (including installation). Such a system would have an estimated lifetime of 20 years. According to Zein (2014), in Morocco an ICS system of this size could collect 1 680 kWh annually, meaning heating up water to an average of temperature of 50°C from an average of 17°C. These are optimistic conditions since the amount of energy collected would primarily depend on the amount of water used. Under these assumptions and compared with a high efficiency water-tube boiler (88 percent efficiency), the energy savings would be USD 225 per year for each 160 litre capacity system installed. If the turnkey price for this capacity is USD 400, then the financial IRR of the system stands at 88 percent[82]. Zein (2014) data then suggest that the major limitation for the use of ICS would not be financial, but rather the system: capacity to heat water only to relatively low temperatures as well as space requirements for larger

80 Based on experts’ opinion. REN21 (2015) reports USD 1 200–3 000/kWp as an indicative cost of ground-mounted PV.

81 Estimated using the tool *Photovoltaic Geographical Information System*: http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php.

82 Even considering that in Morocco such system could be more expensive, the switching point would be at an investment cost of USD 1 100 per 160 litres.

quantities of needed water (no cost of land was considered in the analysis). Thermosiphon or pumped systems would provide a more flexible alternative (water can be heated even above 100 °C) and the financial attractiveness is still expected to be high (IRR above 30 percent).

For wind systems, an illustrative analysis can be made assuming (i) a turnkey price for wind turbines of USD 1 600/kWp[83]; (ii) annual electricity generated by a 1 kWp system of 1 900 kWh; and (iii) the average price of electricity of USD 0.11/KWh. This results in savings in the electricity bill of USD 223/year/installed kWp. In such a situation, the IRR of the investment would be 10 percent. As for PV systems, the results are quite sensitive to changes in electricity price. At a price of USD 0.15/kWh (electricity price at peak period), the IRR would be 14 percent.

Despite the low financial attractiveness of PV and wind, their competitiveness has been rapidly improving given the strong solar and wind resource base (scale) and declining technology costs (IFC, 2013). However, the analysis does not consider land occupation costs and assumes that all energy generated is also consumed or sold. Moreover, given the low financial attractiveness, the cost of financing is a key element that could determine the viability of a PV or energy investment. This point was stressed by several practitioners and stakeholders from the CGEM. Returns to investing in solar and wind energy may also improve if energy prices increase from their current low as the results are very sensitive to electricity prices.

It is clear from the analysis that the installation of back-up batteries to provide electricity on cloudy or non-windy days, which increase investment costs considerably, could compromise the competitiveness of RE technologies. Additionally, if not all the energy that is generated is used, the systems are also not competitive. Hence, for the moment, the competitiveness of RE systems resides with those systems that can be connected to the national electricity grid as back-up and as a way to sell any power surplus that may be generated. Furthermore, the above analysis assumes that all energy produced is consumed or sold to the national grid (PV and wind systems) even though the current regulation has set a threshold that only 20 percent of total electricity generated can be sold to the grid (see Step 4).

83 Based on experts' opinions. REN21 (2015) provides USD 660–1 900/kWp as an indicative cost of wind power installation costs outside the EU and United States. The cost is higher for small-scale systems.

Mitigation cost

Criterion score: **

Indicative mitigation costs were estimated from the simple models described for the financial attractiveness analysis and the grid electricity emission factor for Morocco, net of the life cycle emission of each technology (as estimated by the IPCC). The price of electricity was considered to be its social value. The results (Table 49) are reasonably sensitive to changes in investment and electricity costs and do not include land occupation costs.

Table 49: Estimate of the mitigation cost for the three technologies

		SWH (2 m² - around 1 kWp)	PV (1 kWp)	Wind (1 kWp)
Avoided GHG emission	tCO_2eq/MWh	0.73	0.68	0.72
Annual avoided GHG emission	tCO_2eq	1.4	1.2	1.4
NPV per project year	USD/year	107	-12	-28
Cost of mitigation	USD/year/tCO_2eq	-76	6	-9

Source: Authors' calculations.

Of the three technologies, only SWH systems show a negative cost of mitigation. The results are, however, reasonably sensitive to changes in investment and electricity costs: a 10 percent increase in the estimated average electricity price or decrease in the considered investment costs would render all the mitigation costs negative. In addition, for large plants, ADEREE reported that wind power generation already reached grid parity with coal-fired power plants in Morocco[84].

Data availability

Criterion score: **

Annual energy balance statistics are available from the MEM, which are in turn used by international organizations such as IEA and the United Nations Statistics Division (UNSD). However these data are not disaggregated by energy carriers used in agriculture and food processing and do not include RE consumed by the sector[85]. The national accounts, which provide sector-specific energy data,

84 Source: personal communication during meeting in the fall of 2015 held in Morocco.

85 Sector-specific energy consumption and production data are only available in a few countries, chiefly OECD countries.

currently do not cover RE production. The ADEREE may have more data on renewables but the project team was not able to access such data in time for this report.

Public statistics covering all RE produced in the country could not be found. No repository of RE costs specific for the country could be found, and expert opinions or broad regional cost estimates had to be used instead. The CGEM proved itself a valuable entry point to collect first-hand information from RE practitioners.

Small dams

Table 50: Summary of the techno-economic criteria scoring for small dams in Morocco

Technical assessment			Market assessment		Economic assessment		Data availability
Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	
**	**	*	***	**	*	*	**

Source: Authors' compilation.

Small dams are an effective water catchment solution that can avoid pumping water from underground aquifers, therefore saving energy, typically electricity, and avoiding related GHG emissions.

A comprehensive inventory of all potential sites meeting the technical criteria for the construction of dams in Morocco was developed by the *Comité Marocain des Barrages* (CMB) (2010) in collaboration with the territorial services and local population. It has identified some 1 500 sites with possible technical and economic feasibility, among which 350 have already been studied and included in a database at the Department of Water (CMB, 2010). Based on this, Morocco has set a target for 2030 to build 1 thousand small dams and lakes. The mobilisation capacity of these new facilities is estimated at 600 million m^3 (CMB, 2010).

Technical assessment

Performance compared with international best practice

Criterion score: **

Public-private partnerships (PPP) for the establishment of small and medium dams and hill lakes were initiated in the 1980s. Since then, experts and international companies working on such projects have allowed domestic companies to acquire significant experience in the field. As a result, many technicians have been trained on constructing small dams. Still, according to local experts, issues relating to the management of works and maintenance techniques are not yet completely resolved.

Maturity of technical support services

**Criterion score: **

Past experiences in dam construction have left the country with the necessary experience and Morocco currently exports its expertise to over a dozen countries in Africa and the Middle East. The practice is mature and technological innovations are marginal. According to local experts, some dam maintenance deficiencies can be found in the country, due to the insufficient oversight of users' organizations or a clear mandate of the concerned institutions, rather than a lack of technical knowledge on dam maintenance.

Potential to reduce annual GHG emissions

Criterion score: *

According to FAO AQUASTAT (2016), as of 2013, 68 small dams were in operation and 3 under construction, for a total reservoir capacity of around 63 million m^3. Out of this reservoir capacity, only 33 million m^3 (52 percent of the total) are devoted to irrigation, corresponding to an area of over 200 000 hectares. Moreover, according to CMB (2010), 74 small and medium dams and artificial hill lakes were built in Morocco from 1985–2010 with the capacity to mobilise around 400 million m^3 of water per year dedicated to irrigating around 23 000 ha of cropped land among other uses (household, livestock and recharge of underground water).

Considering Morocco's 2030 target (600 million m^3 mobilisation capacity through 1 000 additional small dams and hill lakes),the following assumptions were made: (i) the new dams would result in the same ratio of volume of water per area effectively irrigated; (ii) conveyance efficiency of 53 percent (AQUASTAT, 2004); (iii) crop irrigation water requirements of 400 mm[86]; (iv) average pumping energy requirement of 1.05 kWh/m^3 (Albegel and Balieu, 2001; Bourarach and Baali, 2013); and (v) the share of dams used for irrigation versus other purposes will remain constant.

With the given assumptions and considering that all water would be used to replace pumped water (rather than create new irrigated areas) the annual reduction of GHG (by 2030) would be around 225 thousand tCO_2eq, making up roughly 1 percent of Morocco's total agrifood sector emissions. Still in

86 In the absence of a national average, the known average for the Doukkala irrigation system (FAO, 2012c) was used.

most cases, small dams would be built in areas where they would not replace pumped water and therefore the actual mitigation potential may be much lower. In fact, as can be seen in the analysis further below and also under Step 3 of the methodology, small dams have other social, environmental and economic benefits that are usually put forward as a rationale for their construction.

Market assessment

Current technology adoption rate

Criterion score: ***

Since 1984, the Water Department of the MAPM has undertaken the implementation of several projects in partnership with local authorities and the National Promotion Office under the Ministry of the Interior. Since then, 74 small and medium dams and hill lakes were constructed, able to mobilise approximately 400 million m^3, as reported above. Since at least 1 000 sites have been identified as feasible by the CMB, there is a large scope for expansion. As indicated above, the expansion may actually take place in areas where small dams will not replace water pumping and therefore energy savings and associated emissions mitigation may be limited.

Trends in gap between current technology uptake and technical potential

Criterion score: **

From the 1980s until today, only small steps were taken toward using all of Morocco's potential for the construction of small dams. Considering the planned increase in water mobilisation capacity of 600 million m^3 from small dams and associated infrastructure in Morocco by 2030, the existing gap between potential and built dam sites is still significant and may gradually narrow. However, despite the natural constraint on the number of sites that are suitable for small dams, the existing gap is not expected to close rapidly given the time required to develop, finance and implement dam construction plans.

Economic assessment

Financial attractiveness

Criterion score: *

Financial costs and benefits

The analysis was made for an average dam that can mobilise 600 000 m^3 of water per year, i.e. the specification for the 1 000 sites identified for construction by 2030. The analysis was carried out for a period of 10 years and construction costs per cubic meter of capacity were considered to be similar to the average of infrastructure already constructed (in the period 1984–2013) with price levels adjusted to 2015. The resulting cost per hectare actually irrigated is quite high at more than USD 10 000. O&M annual costs were assumed to be 2.5 percent of the investment cost, according to national experts' estimates. In order to illustrate potential financial costs and benefits we have constructed a simple model of a small dam with 600 000 cubic meters of water mobilisation capacity and built two scenarios:

- A first scenario where irrigation is already available and where mitigation benefits are expected through savings in energy consumption. The benefits of the small dam that are accounted for include only the savings in terms of costs of water pumping (previously pumped with electrical pumps). In addition, the model assumes: (i) an average crop water requirement of 400 mm per hectare (in addition to rain); (ii) an irrigation efficiency of 53 percent; (iii) an energy demand of 1.05 kWh/m^3 of water pumped; (iv) a price of water saved of USD 0.1/m^3; and (vi) a 12 percent discount rate.
- A second scenario considers benefits from improved water delivery to parts of already irrigated land (resulting in improved income from cropped areas) in addition to the benefits identified in the first scenario. A USD 600 additional positive cash flow per hectare is assumed for those areas with improved water delivery, which represent half of the already irrigated areas (in the case of the simple small dam model used they represent around 17 hectares). The USD 600 per hectare is quite conservative and constitutes around one-third of the net benefits estimated per hectare in the financial analysis of recent irrigation system modernisation projects (World Bank, 2015b)[87].

Both scenarios disregard a number of benefits associated with the creation of dams including water supply for the local population and water availability for cattle.

Financial returns

Under scenario 1, the estimated financial IRR of the investment is below 4 percent, which is not surprising given that there are no extra economic benefits considered beyond energy savings. Adding the extra benefits from irrigated land at USD 600 per hectare for half of the estimated irrigated land, the financial IRR is estimated at 7.2 percent for 17 hectares with improved irrigation. This IRR can reach 11 percent if we assume twice the number of hectares benefiting from improved water delivery (corresponding to the currently observed proportion of land under irrigation from small lands in Morocco).

In sum, the NPV of the investment is negative and the investment would not be attractive from a financial perspective, if only benefits from reduced pumping costs are taken into consideration. To achieve positive returns, other benefits

87 The World Bank's project financial analysis estimated net financial benefits increasing on average by MAD 18 000 per hectare across the different locations. These financial benefits are, however, based on the modernisation of large irrigation schemes and not construction of small dams. In the model used for analysis we consider one-third of the benefits since we are only modelling improved quality of water delivery.

would need to be internalised in such an investment operation including irrigation benefits (from improved water delivery and/or increase in irrigated areas) but also additional ones such as water for livestock, changes in cropping patterns, water availability for nearby settlements, etc.

Mitigation cost

Criterion score: *

Economic considerations

As discussed above, small dams have a public or semi-public good nature and it is important to go beyond the logic of financial investments. Given lack of data on other economic benefits and costs, we have used the simple model constructed under scenarios 1 and 2 and adjusted the construction costs by a 0.9 economic price adjustment factor to reflect average taxes on the initial investment costs. In addition, we have used the 8 percent SDR used throughout this document. The results suggest improved returns but not very high ones.

Mitigation cost estimate

Using the model under scenario 1, the results show an estimated cost of USD 23 per tCO_2eq/year. Even if more optimistic assumptions were made on the area irrigated area benefited by the average dam, the results would never be favourable to the construction of small dams exclusively to avoid GHG emissions from water pumping. Nevertheless, small dams may bring economic and social benefits that can be of key importance for the development and resilience of the agricultural sector locally (see further steps of the methodology). For example, small dams can be used to efficiently irrigate new orchards, which will in turn capture CO_2.

Data availability

Criterion score: *

Data on the identified sites and small dams currently in operation are available at the MEM Water Department and the Ministry of Equipment and Transport. However, the study team did not manage to get access to the official datasets in the required timeframe.

Scattered information and no specific studies could be found to estimate the actual potential to reduce the water that is currently pumped, irrigation water prices or energy sources for the pumps. A more accurate assessment would require a case-by-case analysis through local data gathering and ad hoc research. Finally, it would be important to conduct more detailed studies on the social, economic and environmental impact of small dams.

Results of Step 2

The results of the multi-criteria assessment are summarised in Table 52.

Table 52: Summary of techno-economic assessment of technologies and practices considered for Morocco

Technology or practice	Performance compared with international best practice	Maturity of technical support services	Potential to reduce annual GHG emissions	Current technology adoption rate	Trends in gap between uptake potential	Financial attractiveness	Mitigation cost	Data availability
Conservation agriculture	**	**	***	***	***	***	**	**
Efficient field machinery	***	**	*	***	***	***	***	*
Drip irrigation	**	**	*	**	**	***	***	*
Solar/wind power for water pumping	***	**	**	***	**	***	***	*
Grazing management	***	**	**	***	***	*	*	*
Manure as soil amendment	***	**	**	***	***	*	*	*
Livestock dairy breeds on improved diets	**	**	*	**	**	***	***	**
Efficient water boilers	**	**	*	**	**	**	***	*
Efficient cold storage	***	***	*	**	***	***	***	*
Biogas from manure and agri-residues	**	*	**	***	***	*	*	**
Renewable energy systems	***	***	**	***	**	*	**	**
Small dams	**	**	*	***	**	*	*	**

Source: Authors' compilation.

The results of the techno-economic assessment highlight the technologies/practices that perform better based on the criteria identified in Step 2. These are economic and market-based criteria as well as other technical criteria. The technologies and practices that rank higher according to Step 2 are those that could be introduced under a favourable enabling environment for their uptake given country conditions. However, these are not necessarily solutions that can be deployed to reach their technical potential due to a number of limitations, which could be related to environmental sustainability constraints, social constraints, or other shadow costs from society, meaning they are not the best choice for a given context. These environmental and social constraints which may arise in different sectors (on the energy, water and food sector as well as other co-benefits) will be discussed and addressed in Step 3, which also assesses technologies and practices on the basis of their ability to adapt to climate change.

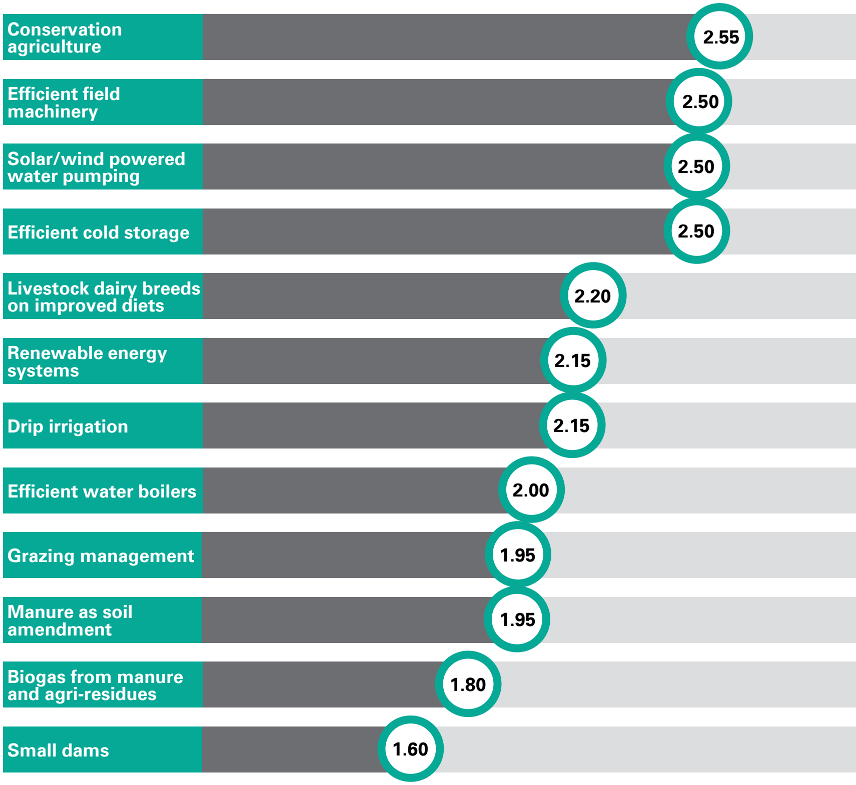
According to the methodology document, specific weights can be assigned to criteria to aggregate the results of Step 2 into one single index which allows the ranking of technologies and practices on the basis of their techno-economic performance. Table 53 reports the weights adopted in this activity. Aggregated results for the techno-economic assessment of the technologies considered are reported in Figure 35.

Table 53: Weights assigned to Step 2 criteria

	Criterion	Weight assigned (total=100)
Technical assessment	Performance compared with international best practice	10
	Maturity of technical support services	10
	Potential to reduce annual GHG emissions	15
Market assessment	Current technology adoption rate	10
	Trends in gap between uptake potential	15
Economic assessment	Financial attractiveness	15
	Mitigation cost	20
	Data availability	5

Source: Authors' compilation.

Figure 35: Ranking of technologies and practices which should be prioritised based on costs, market and technical information in Morocco



Source: Authors' compilation.

The results show a good overall techno-economic performance of CA, efficient field machinery and solar/wind water pumping (which also show high financial attractiveness), followed by RE systems, efficient food cold storage, improved livestock breeding and diets, grazing management, efficient water boilers and manure as soil amendment. Drip irrigation, biogas from agri-residues and small dams rank at the end of the list of the technologies/practices considered from a techno-economic perspective. Again, it should be stressed that positive and negative impacts, including on climate adaptation, have not been considered up to this point of the assessment.

Box 2: The importance of weights in a multi-criteria analysis

An MCA approach like the one applied in Step 2 can facilitate a coherent techno-economic assessment but it is highly dependent on the weights set by the assessor to the different criteria. This choice is subjective and depends on the importance assigned to the different aspects of the analysis.

This method enables an assessment of performance measures, socio-economic costs, and co-benefits, as well as the participation and inputs of local stakeholders to be included when prioritising mitigation efforts. The approach is designed to compare a mitigation option to a reference case or to a set of alternative measures, primarily ex-ante. The MCA method can accommodate a range of measures even if they are hard to quantify or monetise. It also allows the integration of cost-benefit aspects where sufficient data are available. The scores applied can be based on estimates by several experts – an approach that limits the amount of work required. Weights can also be assigned to the criteria through a participatory process.

This relatively simple weighting procedure, as well as the identification of suitable indicators and thresholds, allows for stakeholder participation without significant effort. However, such processes can be resource intensive, and being subjective, may negatively affect the results due to the variety of individual preferences.

Eight criteria were used for the techno-economic assessment in this study, as reported in Table 53. Within this, 35 percent of the final score is attributed to technical or technological criteria, 35 percent to criteria linked to the market, 25 percent to economic criteria and 5 percent to data availability. Furthermore, within each group of criteria, different weights are assigned to each criterion. This weighting system (and the related indicators) is consistent with what is proposed in the methodology document and has been presented and discussed with a number of experts during the development of the methodology. The same weights were also presented and discussed during the two national stakeholder meetings organized in Morocco in March and May 2016. However, it should be noted that the results can vary significantly depending on the assessor and the purpose of the assessment.

The weights proposed in Table 53 and adopted in this study reflect the interests of an investor in the sustainable development and climate change mitigation domain, who primarily seeks to:

- reduce GHG emissions;
- promote a market with good financial returns, and most importantly, maximise the returns in terms of GHG emission reduction vis-à-vis economic costs;
- invest in a technology that can be supported by locally available expertise and services;
- invest in a market that may be large and is not expected to decline soon due to external factors.

This is therefore from the perspective of a government or a financing institution, such as a development bank, whose primary objective is to boost the market for climate technologies that reduce emissions, while maximizing co-benefits (the co-benefits variable is further examined in Step 3). On this basis, the overall results are presented in Figure 35 for:

(i) conservation agriculture
(ii) efficient field machinery
(iii) renewable energy systems
(iv) solar/wind-powered water pumping
(v) efficient cold storage
(vi) livestock dairy breeds on improved diets
(vii) grazing management
(viii) efficient water boilers
(ix) manure as soil amendment
(x) drip irrigation
(xi) biogas from manure and agri-residues
(xii) small dams

If, for example, the assessor is more interested in investing in technologies that are attractive from a financial point of view, regardless of the overall market potential (this could be the case of an agent who is interested in investing in only a few interventions and in a limited timeframe), he or she may assign the following weights:

	Criterion	Weight assigned (total=100)
Technical assessment	Performance compared with international best practice	5
	Maturity of technical support services	5
	Potential to reduce annual GHG emissions	5
Market assessment	Current technology adoption rate	5
	Trends in gap between uptake potential	5
Economic assessment	Financial attractiveness	35
	Mitigation cost	15
	Data availability	25

The new classification of the technologies/practices considered on the basis of Step 2 in Morocco would then be as follows:

(i) conservation agriculture
(ii) livestock dairy breeds on improved diets
(iii) efficient field machinery
(iv) solar/wind-powered water pumping
(v) renewable energy systems
(vi) efficient cold storage
(vii) drip irrigation
(viii) efficient water boilers
(ix) grazing management
(x) biogas from manure and agri-residues
(xi) small dams
(xii) manure as soil amendment

If the assessment is done from the perspective of a public agent who is less interested in creating a functioning market with sustained returns, but more interested in minimising mitigation costs with a limited budget, the weights assigned to the different criteria may be as follows:

	Criterion	Weight assigned (total=100)
Technical assessment	Performance compared with international best practice	10
	Maturity of technical support services	15
	Potential to reduce annual GHG emissions	5
Market assessment	Current technology adoption rate	5
	Trends in gap between uptake potential	5
Economic assessment	Financial attractiveness	5
	Mitigation cost	40
	Data availability	15

On this basis, the resulting classification of the technologies/practices using Step 2 in Morocco would be as follows:

(i) efficient field machinery
(ii) livestock dairy breeds on improved diets
(iii) solar/wind-powered water pumping
(iv) efficient cold storage
(v) renewable energy systems
(vi) efficient water boilers
(vii) conservation agriculture
(viii) grazing management
(ix) manure as soil amendment
(x) small dams
(xi) biogas from manure and agri-residues
(xii) drip irrigation

These examples show that the classification is highly subjective and dependent on the perspective and scope of the assessment. The aggregated results of the techno-economic analysis shown here are from the perspective of a public entity or an institution interested in developing sustainable markets in the long run. It should be stressed that Step 2 (as well as the selection of technologies/practices made on the basis of Step 1) is based on a GHG emission reduction perspective in the agrifood sector and does not consider co-benefits and risks in terms of environmental, social sustainability and CCA at this stage. These aspects are taken into consideration in Step 3.

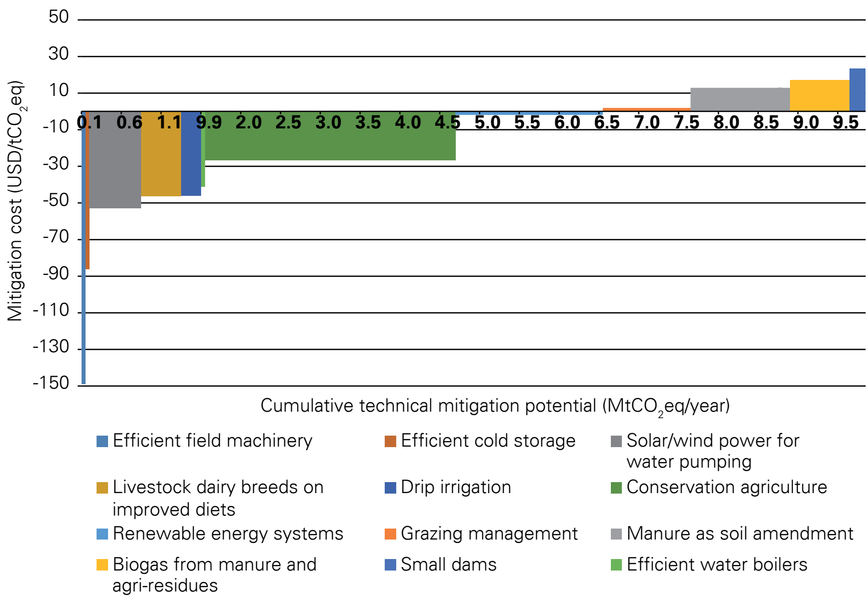
On the basis of the above, it is possible to draw two curves with the estimated cost of mitigation by technology on the Y axis and an indicator of the potential GHG mitigation on the X axis. Figures 36 and 37 have on the X axis, respectively:

- The cumulative technical GHG mitigation potential (calculated to assess the criterion "potential to reduce annual GHG emissions"), thus providing an indication of what would be possible to achieve at a national level in terms of mitigation, regardless of economic, environmental and other barriers and constraints. The area under the MAC curve gives an indication of the associated total cost of agrifood technologies and practices in Morocco. The deployment of all those identified up to their technical potential could avoid around 8.3 $MtCO_2eq$ of GHG emissions.

- The technical GHG mitigation potential of each technology/practice, with the bubble size signalling the other technical criteria, market criteria, and financial attractiveness assessed in Step 2. This gives an indication of which technology could realistically provide the most benefits in terms of mitigation potential in Morocco (leaving aside other environmental, social, regulatory and policy constraints).

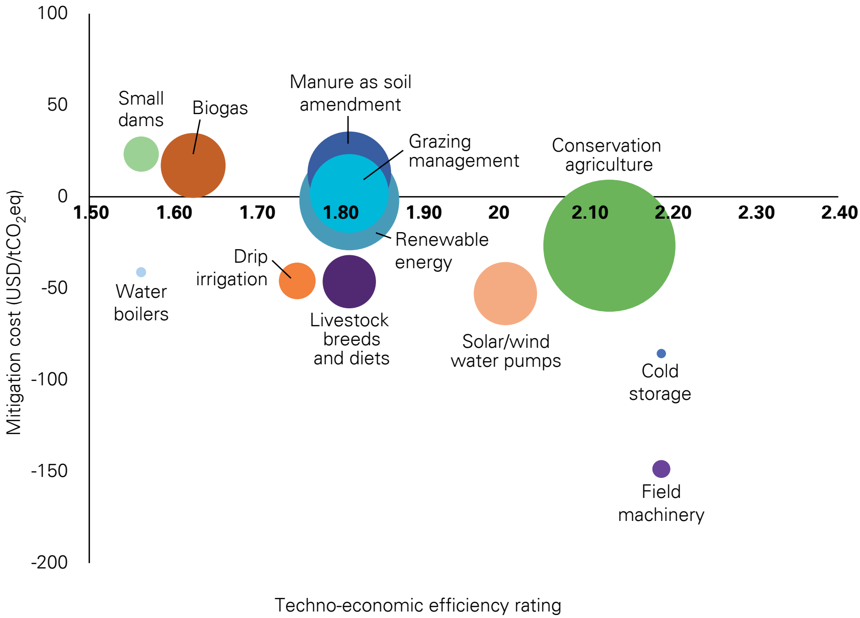
These results will be complemented with information about other sustainability constraints in Step 3.

Figure 36: Estimated cost of mitigation and technical GHG mitigation potential (cumulative) of agrifood technologies and practices in Morocco



Source: Authors' calculations.

Figure 37: Estimated cost of mitigation, other techno-economic criteria and technical GHG mitigation potential by technology/practice



Legend: Estimated cost of mitigation (Y axis), other techno-economic criteria (X axis) and *technical* GHG mitigation potential by technology/practice (size of the bubbles)

Source: Authors' calculations.

Note: The size of the bubble indicates the technical mitigation potential.

Step 3: Evaluating sustainability issues

Step 3 deals with sustainability and other possible unexpected implications of the technologies and practices under consideration. It assesses their suitability in light of key environmental, food security and social objectives and highlights potential synergies and trade-offs that may arise (e.g. as a result of a particular technology being adopted on a larger scale).

From a country (or aggregate welfare) perspective, the real potential of a technology or practice should consider not only its financial, technical and market performance (assessed in Step 2), but also other non-technical constraints (e.g. environmental or social constraints) and evaluate co-benefits, such as implications for climate adaptation. Step 2 focuses mainly on an assessment of technical and financial factors and therefore the analysis is conducted mostly from an individual agent's perspective, even though it also considers economic factors when estimating mitigation costs (these include taxation and subsidies, which are simply internal transfers and not a cost or benefit, respectively) and the potential reduction in GHG emissions (which is a positive externality). As a result, to incorporate important social and environmental aspects in the analysis for a country such as Morocco (and to better assess the different typologies and levels of public support policies), it is important to analyse extra dimensions of social and environmental sustainability to complement the assessment carried out in Step 2.

To simplify the approach, this step of the methodology considers two possible options for undertaking the analysis[88]: (i) a situation in which a technology or practice can have multiple co-benefits and negligible or relatively small trade-offs, in which case a qualitative assessment is sufficient, or (ii) a situation in which important trade-offs may arise, which can make a technology or practice that performs well in Step 2 necessitate a closer analysis in terms of suitability for the specific country context (and possibly the proposal of additional mitigation measures). An example of these latter trade-offs can be a technology that yields significant economic benefits and holds enormous potential to reduce emissions, but that may have negative social impacts through employment reduction for certain segments of the population. In this case, a more thorough and quantitative approach should be performed following, for the most part, the approach of the FAO Nexus Assessment (see FAO, 2014). In this case, a complementary policy to reduce such social impacts may be warranted (which is discussed in Step 4).

88 The choice between each option is determined based on expert opinions and discussions with national counterparts.

Following an adaptation of the FAO Nexus Assessment, Step 3 of the present methodology seeks to evaluate the following four groups of possible major implications for each technology: (i) water, (ii) energy, (iii) land and food security, and (iv) social (including employment, inclusion, gender and others). The relevance of the technology for climate adaptation is also assessed.

The section is organized as follows: the first part summarises the key implications identified for the different technologies and practices based on the analysis. It is followed by the second part, which details the main effects brought about by technology/practice on each of the above-mentioned dimensions. Some of these aspects were to some extent already mentioned in Step 2 for the techno-economic analysis, but here they are discussed and assessed in terms of their countrywide social and environmental sustainability. Finally, a closer examination is conducted of the most "critical" technology identified in Step 3, biogas, using the FAO Nexus Rapid Appraisal, a desk-based application of the FAO Nexus Assessment[89].

Overview of positive and negative implications

Table 54 provides an overview of the main positive and negative implications of the technologies and practices considered along the dimensions described above. These are non-quantitative considerations that the project team identified based on discussions with local experts and literature research. To a great extent, implications are specific to a technology or practice and depend on its socio-economic and technical characteristics, but their relevance and expected impacts also depend on the national context. In particular, the context can be relevant when certain impacts become significant once they are scaled up to the national level, given the technical potential for market penetration.

89 See FAO, 2015b for more information.

Table 54: Overview of overall positive and negative implications of the technologies/ practices considered

Technology / practice	Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)	Relevance for CCA
Conservation agriculture					HIGH
Efficient field machinery	n/a		n/a	n/a	NONE
Drip irrigation				n/a	MODERATE
Solar/wind-powered water pumping					LOW
Grazing management					MODERATE
Manure as soil amendment					HIGH
Livestock dairy breeds on improved diets					LOW
Efficient water boilers	n/a		n/a	n/a	NONE
Efficient cold storage	n/a		n/a	n/a	NONE
Biogas from manure and agri-residues					MODERATE
Renewable energy systems					LOW
Small dams					HIGH

Colour code:

	Overall positive impact
	The overall impact is neither positive nor negative
	Overall negative impact

Source: Authors' compilation.

The analysis highlights that technologies and practices that may perform well in Step 2 (techno-economic analysis) may need a particular focus on management in order to avoid unwanted negative impacts. In fact, certain technologies should be introduced with care in Morocco because of local constraints, even if they would not signal any relevant trade-offs in other countries (e.g. in water rich or wealthier countries).

In our analysis, this group includes:

- Drip irrigation: while this technology has positive water, land and food security implications, it could lead to higher energy consumption in certain contexts due to the intensification of agriculture. It also requires appropriate territorial planning as it may influence water availability patterns in the watershed.
- Conservation agriculture: CA offers positive water, energy and land and food security implications, but may require more skilled workers. However, this gap in labour skills may spur additional training and workforce development, translating into social benefits in the long run.
- Solar/wind-powered water pumps: these technologies will enable lower fossil fuel consumption and improved land, food security and social conditions, but may encourage higher groundwater exploitation.
- Grazing management: water, land and food security and social implications are positive, but this technology would necessitate higher energy needs for land restoration and infrastructure.
- Manure as soil amendment: management of manure and associated infrastructure may require additional energy consumption, despite positive water, land and food security and social implications.
- Livestock dairy breeds and improved diets: this technology offers positive water, energy, and land and food security implications, but may endanger labour opportunities and gender issues.
- Biogas from manure and agri-residues: despite positive energy implications, biogas may have a negative impact on water implications (increased water needs, risk of water pollution), land and food security implications (competition with other uses of residues, over-extraction of residues), and social implications (need for more skilled labour), though the latter constraint may encourage skills development within the local workforce. This appears to be the most critical technology considered on the basis of the qualitative assessment done in Step 3 and may deserve a more quantitative analysis.

Despite these constraints, the aforementioned technologies do not present major sustainability risks. Although certain technologies or practices merit particular attention (yellow or orange areas in Table 54) this does not mean that their development should be discouraged; rather, their deployment should be planned with care and further development or investments in the technology would need specific monitoring and safeguards. Meanwhile, according to our analysis, the technologies with no potential trade-offs include RE systems, small dams, efficient field machinery, efficient water boilers and efficient cold storage.

Moreover, it should be highlighted that CA, use of treated manure as soil amendment and small dams are expected to provide the largest benefits in terms of CCA in Morocco among the technologies/practices considered. Drip irrigation, grazing management and biogas also bring important benefits for climate adaptation, while "energy efficient technologies" such as efficient field machinery, boilers and cold storage do not impact adaptation.

Biogas production may have important sustainability trade-offs and therefore merits a more in-depth analysis involving local stakeholder consultations following the FAO Nexus Assessment methodology. An application of the FAO Nexus Rapid Appraisal (a simple desk application of the full FAO Nexus Assessment) for biogas is therefore conducted later in this report.

Conservation agriculture

CA touches upon all "nexus aspects" with generally positive implications on sustainability. In addition, it also scores positively for contribution to CCA.

Table 55: Analysis of sustainability implications of conservation agriculture

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
• Positive impact through reduction of surface runoff • In the absence of rotations there is potential for groundwater contamination due to increased use of herbicide and fertiliser	• Positive impact through reduction in aggregate diesel consumption	• Positive impact on long-term soil fertility • Reduced yield volatility due to improved results under drought conditions • If soil coverage is applied there may be competition with the use of residues as animal feed	• Less time spent on soil work and shorter delay in optimal sowing time • More skilled workers may be needed to operate direct seeders and they may not be locally available

Source: Authors' compilation.

Water implications. According to most available empirical research worldwide (Richards et al., 2014), soils under low tillage have higher water infiltration capacity and lower surface runoff compared to conventional agriculture. Evidence in Morocco also seems to suggest a positive impact of CA on water retention. For example, in the climatic conditions of Sidi El Aidi, direct seeding mulch increases the amount of water available for wheat compared with conventional tillage (Bouzza, 1990; Mrabet, 2000). However, under certain conditions, CA can also have some negative consequences through increased chemical use (Mrabet, 2001), especially in the absence of crop rotation, when farmers have to use more herbicides. As indicated in Step 2, Boughlala (2011) and discussions with experts in Morocco suggest that no-till would result in increased fertiliser and herbicide use only in the short term by about 5 percent each. However, in the long term, correct adoption of CA is expected to result in net reductions in both.

Energy implications. As already indicated in Step 2, CA can lower on-farm energy by reducing tractor use or other machinery that is normally used for tillage (Dycker & Bourarach, 1992). Most evidence points to significant savings in diesel consumption (around 30 litres of diesel per hectare per year) which, given the technical potential for CA in Morocco, would translate into significant energy savings in a country that is a net fuel importer. As an illustration, assuming 1.5 million hectares were converted to CA, one could expect up to 45 million litres of diesel saved, which at current local prices (USD 1.02/litre) would translate into a significant amount of savings: over USD 45 million annually (more than 0.3 percent of the value-added of agriculture in Morocco).

Land and food security implications. One of the key reported benefits of CA is in improving long-term soil fertility and therefore yields. Most importantly, CA is reported to result in major yield improvements relative to conventional practices, especially in dry years. This is particularly relevant in Morocco, where yield volatility is a major problem because of droughts. Farmers using reduced tillage typically report higher yields with lower water costs and fertiliser use. In favourable areas in Morocco (e.g. the Meknes region), Aboudrare and El Qortobi (2001) showed that direct seeding is effective at reducing GHG emissions while maintaining yields in both dry and wet years. In dry years, yield gains range from 53 percent to 155 percent compared to the conventional system.

The soil moisture level is often an important limiting factor in agricultural productivity. It has been widely reported by many authors that conservation techniques based on direct seeding increase the moisture content in the soil profile in comparison with conventional techniques. This allows the microorganisms and fauna to ensure a balance of nutrients in the soil – a natural process disrupted by mechanical tillage. Bessam and Mrabet (2001) found that the organic matter content changes dramatically under direct seeding over time, while under conventional tillage, soil largely maintains the same rates. Mrabet et al. (2001) found that the levels of phosphorus, nitrogen and potassium improve with no-till compared to conventional tilling.

With CA, farmers may spend considerable time on soil preparation, which can delay the date of sowing beyond an optimal time. This is one of the main causes for low yields amongst CA adopters.

Social implications. CA therefore offers the benefit of minimum soil disturbance, enabling farmers to increase production by spending less time on soil work. Despite this social benefit, CA may bring negative consequences for employment: reduced tillage usually requires skilled workers for a shorter working period to drive the tractors and use the drilling seed machines, which may be difficult to find locally. However, this shortage may drive the acquisition of new skills within the workforce, contributing to the diversification of the labour pool and bringing more skilled employment opportunities into the economy.

Relevance for climate change adaptation. Climate change can cause soil erosion and loss of fertility, reducing agricultural productivity over time. Minimum soil disturbance increases soil biodiversity and organic matter content and contributes to the physical stabilisation of the soil structure.

Minimum soil disturbance improves drought resilience by increasing the water conservation capacity of the soil. The residues left on the field, especially surface mulch, limit evaporation from the soil. The results published in Mrabet (1997) show that ground evaporation in non-tillage with mulch is smaller than in various tilling systems and the temperature of the soil surface is closer to optimal due to the mulch. Mrabet also showed that minimum soil disturbance contributes to a longer dry-out period of soils when there is a canopy, but overall no-till is favourable for absorbing rainwater. This hydrological behaviour of soil is particularly relevant for early plantations in North Africa.

Efficient field machinery

Efficient management of field machinery is a practice that performs well in terms of energy implications because it translates in fossil fuel savings. The effects on climate change resilience are negligible.

Table 55: Analysis of sustainability implications of efficient field machinery

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
n/a	Fuel consumption on farm is reduced	n/a	n/a

Source: Authors' compilation.

Energy implications. The number of tractors used in Moroccan agriculture has continuously grown over the last two decades (Trading Economics, 2015), resulting in a substantial increase in energy consumption (Jaouhari, 2013). In particular, the PMV has been key to promoting the mechanisation of agriculture, which has encouraged the use of more modern agricultural machinery in the sector.

More efficient tractors and improved use of machinery both reduce on-farm energy use since less diesel is consumed per unit of work done. Diesel is in fact the largest energy carrier in agriculture (40 percent of the total) with 32.5 PJ consumed in 2012 only (from 2016 MEM statistics). After Morocco's mechanisation boom in 1957–1961, which relied on former Soviet equipment models (which remained in use until the 1990s), in the last two decades, various international tractor suppliers (mainly European) entered the market[90], therefore contributing to an increasing efficiency of engines. Newly purchased machinery in Morocco is more efficient in terms of fuel consumption per work done (Fellah Trade, 2011), even if energy consumption in absolute terms increased significantly (Jaouhari, 2013) due to the growth in tractors over the last two decades driven by the PMV. There are only insignificant implications with regards to water, land and food security and social implications, nor are there significant implications for CCA.

Drip irrigation

Drip irrigation has an outstanding performance in most aspects of the nexus, but it can lead to higher energy consumption rates if the water savings do not offset the energy needed to pressurise the system (cases of shallow water extraction). Hence, the conversion of surface irrigation to drip irrigation is considered a climate technology only when the water lift is equal to or above 10 meters. Even in cases in which energy needs increase, it remains a relevant technology for adaptation to climate change.

Table 57: Analysis of sustainability implications of drip irrigation

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
• Reduces water run-off and evaporation, hence irrigation water is used more efficiently • Less surface water availability on the field can decrease underground water availability farther downstream	• Energy consumption decreases compared to surface irrigation when groundwater is used • Could lead to more energy consumption from the intensification of agriculture	• Agri-chemicals can be applied more efficiently and precisely • Can improve yields	• n/a

Source: Authors' compilation.

90 See for example http://agriculture.newholland.com/me/en/WNH/news/Pages/2014_SIAM_news.aspx.

Water implications. Drip irrigation helps use water efficiently by reducing water run-off through deep percolation or evaporation. To complement the ambitious goal of the Moroccan government (MADRPM, 2007) to equip 550 000 ha (or 50 percent of the total irrigated land) with drip irrigation by the year 2022, field tests found that 40–46 percent of irrigation water has been saved by drip irrigation systems compared to surface irrigation considering several crops and locations (Berrada, 2009: p.11, Table 7). Other case studies showed considerable reductions in irrigation water demand for certain crops, herbs and vegetables (FAO, 2012c).

In some cases, the introduction of drip irrigation on land previously under surface irrigation can introduce water availability problems for irrigation downstream due to the lower recharge rate of underground aquifers.

Energy implications. As discussed in Step 2, the pumping energy coefficients developed by Savva and Frenken for FAO (2001: p.36) indicate that drip irrigation can be considered a mitigation technology for water pumped from a static lift of 10 metres or higher. Additionally, due to the reduced amount of irrigation water demand, the total energy balance is in favour of drip systems – a result that is substantiated by the FAO study in the Doukkala region of Morocco (FAO, 2012c), which conducted techno-economic assessments of various plantations. Therefore, drip irrigation, under the conditions considered here, results in energy savings.

Land and food security implications. Doukkali and Lejars (2015) estimate that the subsidy of MAD 111 000/ha to irrigated crops thanks to the National Irrigation Water Saving Project in Morocco, on top of subsidies allocated to other agricultural investments (machinery, buildings, greenhouses, etc.), can lead to the intensification and expansion of agricultural activities, which may therefore increase energy consumption in the sector due to the rebound effect.

Chemicals can be applied more efficiently and precisely with drip irrigation following the physiological cycle of the plants or crops: since only the root zone is irrigated, nitrogen that is already in the soil is also less subject to leaching. Drip irrigation can thus improve crop yield by 10–100 percent depending on the crop, as illustrated by Berrada (2009: p.2) in Morocco; FAO also estimates a substantial improvement with a yield increase of 98-126 percent (2012c: p.13).

Relevance for climate change adaptation. Drip irrigation allows more efficient water usage, leading to increased resilience of agricultural production to climate change, especially where water availability is already limited. Drip irrigation only irrigates the crop root zone (Berrada, 2009: p.vii), therefore nitrogen that is already in the soil is less subject to leaching (Berrada et al., 2006).

Finally, drip irrigation might have additional CCA benefits. In fact, despite occupying only 15 percent of the cultivated area, irrigated agriculture in Morocco contributes to on average 45 percent of the agricultural value added and 75 percent of agricultural exports (MAPM, 2015a). This contribution is particularly important in years of drought, when production in pluvial areas is severely affected. For instance, during the drought in 1994–1995, irrigated agriculture contributed to 70 percent of the agricultural value added (MAPM, 2015a).

Solar/wind-powered water pumping

Solar and wind-powered water pumping for irrigation alleviate pressure on fossil energy resources, but can have important unintended impacts on the water sector due to overexploitation of the groundwater resources, especially where water is scarce. They also enable farmers without access to the national grid to manage water actively, therefore promoting adaptation to climate change.

Table 58: Analysis of sustainability implications of solar/wind-powered water pumping

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
• "Free" energy may lead to groundwater overexploitation	• Fossil fuels and electricity consumption are reduced	• Irrigation can overcome power outages (although this is not a major problem in Morocco), and be operated in remote areas • Promotes decoupling of food production from the energy market	• The illegal use of butane for irrigation in remote areas is avoided, easing the cost of the butane subsidy on the society

Source: Authors' compilation.

Water implications. Due to reduced operation costs for pumping, as tested in Economic and Social Commission for Western Asia (ESCWA) countries (including Morocco), a rebound effect might result in excessive and unsustainable water pumping (Zein, 2014). This would therefore lower the underground water table or reduce surface water availability since the farmers have no immediate financial incentive to limit water pumping. However, no such experience could be specifically identified in Morocco.

Energy implications. Solar/wind water pumps replace fossil fuel-powered pumps, thereby decreasing pressure on fossil fuel resources.

Land and food security implications. The introduction of this technology will enable sustained yields during power outages. As discussed by Zein (2014: p.65), the installation of RE sources to remote areas offers an option to power equipment in the absence of or inadequate access to the national grid. However, this does not seem to be a major problem in Morocco. Overall, reduced reliance on fossil fuels helps to decouple food production from the energy market.

Social implications. In Morocco, solar/wind pumping can substitute the illegal use of butane for irrigation in remote areas, thereby decreasing the cost of the butane subsidy for the state and society (MEM, 2015). At the same time, however, this technology may not be universally accessible due to higher investment costs.

Relevance for climate change adaptation. Solar/wind-powered pumps can enable the farmer to actively manage water. This can increase resilience to climate change in places where water management is passive. These technologies can also allow the timely and precise withdrawal of water so that farmers can effectively cope with variable climate such as delayed or inadequate rain during the planting season.

Grazing management

Improved management of pastures has positive implications for all the elements of the nexus except for energy use. It can also contribute to CCA by mitigating soil erosion.

Table 59: Analysis of sustainability implications of grazing management

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
• Soil hydrology improved	• Additional energy needed for land restoration and infrastructure	• Increased productivity of the livestock • Improved productivity contributes to higher livestock fertility rates, better health conditions and decreased mortality rates of the stock	• More labour may be needed for active grazing management, which could generate additional employment opportunities • Implies value chain development generating new opportunities for income generation

Source: Authors' compilation.

Water implications. Improving vegetation through grazing management positively impacts soil hydrology by preventing erosion, the deterioration of riparian vegetation and nutrient run-off. Within the context of available empirical evidence, the benefits of this technology would likely be relevant in Morocco[91].

Energy implications. Complex grazing management programmes aim to restore degraded lands and construct infrastructure for the grazing stock. As a result, they likely incur additional energy needs for the manufacture, installation, and operation of infrastructure. Empirical evidence shows that this is a relevant issue in Morocco[92].

Land and food security implications. Improved productivity in grazing systems, especially those relying on marginal land (e.g. pastoral), contributes to food security by improving the fertility rate and health conditions of the stock while decreasing mortality. IFAD (2002a) reported a fertility rate improvement of 10 percent and a mortality rate drop from 6 to 2 percent over the 10 years of the grazing management project. Additionally, better grazing systems also enhance the productivity of the livestock. For example, the latest reports from the field in Morocco show an increased gross margin of up to USD 60 per ewe per year[93]. This is also thanks to the additional dry matter on pastures.

Improved grazing management also has positive impacts on biodiversity. UNDP (2010) reported a significant decrease in biodiversity loss as a result of the Transhumance for Biodiversity Conservation project in the grazing-dependent ecosystems of the Southern High Atlas in Morocco.

Social implications. Active management of grazing land requires additional labour. Although the needs are not signification, this could generate more employment opportunities, thereby incurring positive implications for the wider economy. The improvement of grazing lands may be coupled with value addition of their associated products, which can have positive effects on local incomes with the appropriate development of products and value chains.

Relevance for climate change adaptation. Improved grazing practices are beneficial for climate change resilience through enhanced vegetation and ultimately higher resistance to climate-change related soil erosion.

Manure as soil amendment

The practice of properly managing manure on-farm and treating it for subsequent application to the soil has an impact on all nexus aspects. With the exception of higher potential energy demand (for handling and treating the residues), manure management has positive implications on all elements of the WEF nexus. The practice is also relevant for CCA when combined with manure treatment (e.g. into compost) as it ensures that nutrients and organic matter

91 See for example IFAD (2002b: p.ix).

92 For more information, see IFAD 2002a.

93 Araba, A., personal communication.

are efficiently returned to the soil where most needed, thus contributing to productive and resilient soil.

Table 60: Analysis of sustainability implications of manure as soil amendment

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
• Improved equipment for manure management prevents nutrient leakage and pollution	• Management of manure and the associated infrastructure can require additional energy (which could be largely offset by biogas or high value soil amendment production)	• Treated manure applied to soils can contribute to higher yields than untreated manure	• Converting agri-residues to compost reduces public landfill disposal costs • Can reduce bad odour from stacked manure • Can reduce pollution

Source: Authors' compilation.

Water implications. With concentrated livestock and manure handled on-farm, 15 tonnes of manure per LU is produced annually (Rafrafi & El Mostafa, 2006), of which 50 percent is liquid, elevating the risk of leaching and contaminating groundwater. According to Sabir (2010), traditional manure handling practices in Morocco increase the risk of leaching nutrients and harming the water base, especially with unprotected storage of manure on the field. The same risk is confirmed for manure management at dairy farms by Aghzar et al. (2002), who found significant groundwater deterioration due to nitrate pollution from manure. Manure management, including the installation of non-permeable stable floors, controlled manure handling and storage in tanks effectively prevents leaching, while protecting the surrounding natural waters.

Energy implications. This technology requires additional energy from a number of sources, notably the installation of physical and operating equipment for frequent manure removal, treatment, storage and application, as well as the formulation of terraces on slopes for controlled and gradual leach-off (Sabir, 2010). These inputs might be effectively offset by the reduced energy demand from manufacturing and applying artificial fertilisers, as well as possible biogas applications made possible by the controlled management of manure.

Land and food security implications. As the analysis of Assobhei (2009) shows, 77 percent of agricultural residues in Morocco are high-nutrient manure with a positive impact on soil consistency, if managed and spread properly. Improved manure management can have a positive impact on crop yields through the nutrients saved for field application, especially for small farmers involved in the intensive production of horticultural crops in Morocco, who rely strongly on cattle manure (FAO, 2011b).

Social implications. Using manure and agri-residues for compost limits the amount of organic material that must be disposed of in landfills, further contributing to reductions in public expenditure.

Relevance for climate change adaptation. The application of manure as a soil amendment decreases dependence on chemical fertilisers. By using compost from manure, farmers recover degraded soils (Assobhei, 2009; Rafrafi & El Mostafa, 2006) in areas affected by climate change. Increasing organic matter in the soil is fundamental to maintain soil fertility and a resilient production system to climate change, especially in semi-arid areas.

Livestock dairy breeds on improved diets

The improvement of livestock dairy breeds and their diets can have an impact on all aspects of the nexus, with some limitations in terms of behavioural change imposed on farmers and risks of increased water consumption. There is a debate about whether improved or local breeds better promote livestock systems' resilience to climate change.

Table 61: Analysis of sustainability implications of livestock dairy breeds on improved diets

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
• Water use intensity per unit of animal product is higher • More water will be needed to produce the animal feed to allow a shift towards more productive breeds	• Energy use intensity per unit of animal product is lower • More energy may be needed to produce the animal feed but this is not seen as a major sustainability concern	• Feed intake efficiency improves and therefore the amount of fodder per unit of product • Land use competition between food and animal feed is foreseen but this is not seen as a major sustainability concern	• The introduction of improved breeds may endanger labour opportunities, gender issues and soil fertility

Source: Authors' compilation.

Water implications. The breeding of less productive dairy livestock with more productive breeds effectively reduces the amount of water used per kg of product, as reported by Srairi et al. (2013). In 2009, 1.7 m^3 of total water was needed to produce 1 kg of milk in Morocco and 9.1 m^3 were needed for 1 kg of live weight gain (crossbred). Moreover, simulations carried out for a 2 ha farm in Morocco showed that replacing crossbred with Holstein cows tripled water productivity (however better diets were required to reach the optimal lactation performance, which in turn partially increases the use of virtual water) (Srairi, 2009). However, since in Morocco it is assumed that the potential for improved breeds and diets is possible only on (or close to) irrigated land to produce animal fodder, the impact on water resources in absolute terms will be negative (i.e. more water will be needed to produce feed for improved breeds on improved diets). This may be a sensitive issue in Morocco.

Energy implications. FAO (2011) lists the various benefits of improved productivity of Moroccan dairy herds, including reduced energy use per kg of product. This includes fodder-related energy inputs as well as other external energy inputs associated with production. More energy will be needed if the improved breeds rely on irrigated feed production, however this is not seen as a major sustainability concern in the country.

Land and food security implications. Gains in efficiency and productivity for breeds on better diets ultimately result in higher milk and meat output. Projections of improved dairy herds in Morocco from the current average milk yield of 1 895 litres/cow to the desired 2 731 litres also forecasts better feed intake efficiency (Araba, 2015)[94], thus resulting in less fodder diverted to produce the same amount of animal product. However, in absolute terms, more land is expected to be needed to produce the feed for the improved diets, which may lead to some competition with land use.

Social implications. Small-scale livestock production often has a positive social role in labour opportunities, gender issues and soil fertility preservation (Srairi et al., 2003), which might be endangered with the intensified dairy structure change associated with productive breeds. This technology may introduce social inequalities as well, as members of lower socio-economic groups may not enjoy the same level of access due to financial constraints (for more information, see Step 4).

Relevance for climate change adaptation. There is a debate on what livestock systems can more effectively increase climate change resilience in Morocco. Local breeds are generally already adapted to harsh living conditions and survive in periods of low feed availability – although with significant productivity decreases. Improved traditional herding systems might increase resilience in cases where there is no capacity to ensure feed from irrigated land in periods of reduced rainfall. Local breeds are mostly suitable for meat production and are highly inefficient when producing milk.

On the other hand, well-fed, healthy, pure dairy breeds are much more efficient at using feed and water to produce milk. Hence, those with secured feed in dry years will make better use of scarce water resources to secure a stable milk production.

94 Projections of national dairy herd productivity shared by Araba, A, 2015.

With regard to securing stable domestic milk production, farms producing small quantities of milk from local breeds are vulnerable to climate hazards, particularly drought, and milk output is largely dependent on rainfall levels. Therefore, modernised stocks can help farmers become more resilient to a changing climate (FAO, 2011b: p.20).

Efficient water boilers

Because the diffusion of efficient water boilers is essentially an energy efficiency intervention, it has a relevant sustainability impact on energy consumption (on top of the economic benefits highlighted in Step 2).

Table 62: Analysis of sustainability implications of efficient water boilers

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
n/a	• More efficient fossil fuel usage	n/a	n/a

Source: Authors' compilation.

As providers of heat and steam for the food processing industry, fuel oil-powered water boilers demand a large share of energy of the sector. The refurbishment, potentially necessary for one-third of the operational boilers in the country, would reduce the amount of fuel used by the sector on the order of 10–15 percent per boiler.

Efficient cold storage

Similar to efficient water boilers, improving the energy efficiency of cold storage for food has a relevant sustainability impact on energy consumption (on top of the economic benefits highlighted in Step 2). This contributes to climate change mitigation, while being neutral to other elements of the WEF nexus.

Table 63: Analysis of sustainability implications of efficient cold storage

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
n/a	• More efficient electricity usage	n/a	n/a

Source: Authors' compilation.

The efficiency measures proposed for cold storage only affect the energy consumption of the facilities, and ultimately enable more efficient use of fossil fuel resources. The latest data from Morocco reports approximately 1.3 GW of installed power for cold storages (MEDISCO, 2008). Significant energy savings could be reached by avoiding energy loss due to bad insulation or outdated cooling equipment.

Biogas from manure and agri-residues

Biogas systems require particular care to mitigate the risk of unexpected negative impacts on natural resources and social aspects. Besides a clear positive impact on energy use as a clean energy alternative to fossil fuels, biogas systems might raise some concerns in terms of water and food security if not carefully planned within the local context. The relevance for CCA is low but increases significantly if the resulting digestate can be used to maintain soil fertility and to decrease the dependence of the farm on external inputs.

Table 64: Analysis of sustainability implications of biogas from manure and agri-residues

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
• Freshwater is needed to dilute the biogas feedstock • Biogas effluents can pollute the watershed if not treated properly	• Reduces fossil fuel consumption and promotes decoupling of food production from the energy market • Recovered fertiliser contributes to lower demand for energy-intensive conventional fertilisers	• Competition with other uses of residues (e.g. as soil amendment or feed) • The over-extraction of residues from the field can negatively affect soil fertility • Nutrients and organic matter contained in the resulting digestate can be returned to the soil where most needed	• Biogas can reduce bad odour (e.g. from stacked manure) • The commercialisation of the biogas produced can provide additional revenues to the farmer, thus diversifying income • In areas where solid fuels are largely used, biogas provides an alternative to cooking fuels, thus reducing indoor pollution • Additional skilled labour is needed to run the biogas system

Source: Authors' compilation.

Water implications. When the biogas is produced from agricultural residues, additional freshwater is needed for biogas production. This is because the water content of manure or crop residues is usually too low to ensure optimal anaerobic conversion of the biomass. Moreover, the resulting effluents from a biogas plant can pollute the watershed if they are not properly treated before discharge.

Energy implications. Considering the theoretical potential to recover over 87 million tonnes of organic waste in Morocco (Afilal, 2013), by governmental estimates the country's potential for biogas production exceeds 20 PJ, which means a contribution of around 3 percent to the energy mix as of 2011 (MEM, 2011).

For livestock farmers in particular, manure has the possibility to reduce farm dependence on external energy inputs (fertilisers and soil conditioners). In fact, the resulting digestate (the by-product of biogas production) can be used as fertiliser, thus contributing to lower the demand for energy-intensive fertiliser.

Land and food security implications. The use of agri-residues as feedstock for biogas production can compete with alternative uses of residues, such as feeding livestock or as soil amendments in agriculture. There is also a risk that the over-extraction of animal and crop residues from the field and diverting them for energy production can negatively impact soil fertility and health.

A good amount of nutrients, moisture and organic matter can be returned to the soil after the biomass process in the form of digestate (Afilal et al., 2010), which has some improved chemical-physical characteristics if compared to the direct application of residues to soils.

Social implications. Modern biogas digesters reduce the odours from manure, particularly through manure storage. The replacement of firewood with biogas for cooking also contributes to a reduction in local and chiefly indoor air pollution. Moreover, farmers' incomes become more diversified through the possible sale of biogas, electricity and digestate (Zein, 2014; Abarghaz et al., 2011).

However, this technology may not be available to all socio-economic classes due to the costs involved (see Step 4). Additionally, specific skills and know-how is required (Zein, 2014); although currently lacking, this could create interesting opportunities for developing new skills and jobs in the Moroccan economy.

Relevance for climate change adaptation. Biogas alleviates climate-related pressure on resources. Specific pressures that can be avoided include energy outages and yield decreases due to drought, which could be addressed through the application of digestate. Digestate improves water retention in the soil and more broadly, it can provide an effective source of organic matter to be managed and applied to soils most severely affected by climate change (thereby preventing erosion, increasing water retention, etc.).

Renewable energy systems

RE systems, limited in this report to PV, SWH and wind systems, include a broad range of technologies under one single category. For this reason, this group can potentially impact all nexus aspects. It has a direct positive benefit on the energy sector, while negligible trade-offs exist with access to capital and the water sector.

Table 65: Analysis of sustainability implications of renewable energy systems

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
• Very low amount of water needed for PV systems; none for other technologies • Indirectly saves water needed for electricity generation and fossil fuel extraction	• Fossil fuel consumption is reduced	• Renewables enable pumping for irrigation, drinking water, cooling, electrification and telecom which are all activities that ultimately improve food security • Large land areas may be needed for PV plants, but this is not a problem in Morocco	• Distributed RE systems contribute to the diversification of incomes and help decouple food production from the energy market • New business opportunities linked to the RE market or due to increased energy access

Source: Authors' compilation.

Water implications. Water use will vary depending on the source and type of RE being generated. However, water use is low for PV systems (limited to regular cleaning of the PV panels) and negligible for wind turbines and SWH.

RE displaces fossil fuels and electricity (largely generated from fossil fuels), which both demand important water resources for their production/generation (e.g. water is needed to cool power plants and to extract fossil fuels). However, in the case of Morocco, fossil fuels are mainly imported and therefore the indirect water consumption due to their extraction does not notably affect national water resources.

Energy implications. The primary goal of these systems is to reduce fossil fuel use and to power remote equipment outside the range of electricity grids or cheap fuel. IEA (2016b) reports that the share of renewables in the energy mix of Morocco includes only wind and hydro-power, with wind energy contributing 1 481 MWh annually – quite a low quantity. There are numerous solar water heaters and PV systems already operating in the country (Zein, 2014), but their contribution is still marginal.

Land and food security implications. As Zein (2014) notes regarding the ESCWA region, including Morocco, RE systems potentially contribute to agriculture in remote areas without grid connection or with unreliable grid connection, thereby enabling (i) water pumping for irrigation and drinking; (ii) drinking water purification; (iii) solar cooling; (iv) village electrification; and (v) telecom applications. These applications indirectly contribute to better use of land resources and enhanced food security.

RE, especially PV, may require large land areas to install panels. This land could be used for other purposes, including agriculture, but in general this is not a problem in Morocco.

Social implications. Energy generation, especially on-farm, can diversify a farmer or operator's income, or reduce the dependency of the agrifood sector on the energy market. It can also facilitate the establishment of new businesses while increasing energy use efficiency. Consequently, distributed generation has important social benefits. However, this technology may not be accessible to all socio-economic classes, and may exacerbate inequality (for more information, see Step 4).

Relevance for climate change adaptation. In remote locations, RE can also be used to cook, dry or process food in order to provide effective nutrition or to store food for longer periods of time, thus reducing dependence on climate. It can also provide timely access to energy for various active management agricultural activities such as irrigation or greenhouses to overcome extreme climatic events. However, off-grid communities and unreliable electricity grid are not common in Morocco, therefore the relevance of the technology for climate adaptation is limited.

Small dams

In this study, small dams are seen as a water catchment alternative to underground water pumping for irrigation. Therefore, the main impacts are on energy aspects but important indirect co-benefits on other aspects of the nexus exist. Small dams for water capture have no major impact on the WEF nexus in Morocco, where generally positive synergies can be found among nexus aspects. Small dams, as well as other water catchment solutions in general, also contribute significantly to CCA.

Table 66: Analysis of sustainability implications of renewable energy systems

Water implications	Energy implications	Land and food security implications	Social implications (incl. employment)
• As a water catchment solution, small dams contribute to water security for irrigation and aquifer recharge • If they are well managed, the dams should not significantly impact the ecosystems downstream	• Energy otherwise needed for pumping water from the aquifer is saved (if built to irrigate new areas, however, energy consumption will increase) • Surplus water can be used for hydropower thus further reducing fossil fuel usage	• Intensive horticulture is enabled where otherwise impossible or costly • Marginal land can be put into production, thus contributing to its restoration • These benefits materialise without increasing energy use if irrigation is done downstream from the dam by gravity	• The construction of small dams contributes to local poverty alleviation generating new (skilled) jobs • Given the long payback time, the cost of building small dams is normally borne by society

Source: Authors' compilation.

Water implications. Small dams directly improve water security by preventing runoff, contributing to infiltration and providing a source of continuous irrigation water for nearby cropland. The benefits of small dams have been internalised into Moroccan national policy. As a result of its policy of building one dam per year, Morocco now has 26 hydro power stations totalling 1 360 MW in capacity, and future developments are planned[95] (see Step 4 for more details).

Energy implications. Small dams contribute to decreased energy consumption (and cost) of water pumping in areas where surface water resources are scarce or unavailable.

Land and food security implications. Small dams also facilitate intensive horticulture through increased availability of irrigation water, thereby providing higher yields and positively impacting food security[96]. Additional captured water can also be used to cultivate marginal lands, thus contributing to land restoration and the increased storage of organic matter in the soil. Irrigating more areas will often imply increased energy requirements, i.e. a food-energy trade-off.

If not all water is used for irrigation, small dams can also be used to generate hydropower. By providing RE produced by the water pressure of the reservoir,

95 See http://www.moroccotomorrow.org/business/green-business/.

96 See for instance: http://www.ifad.org/english/water/water_food/docs/reservoirs_indicator.PDF.

small dams contribute to the annual 2 990 GWh hydropower generation of Morocco (IEA data for 2013[97]).

Social implications. The recent development plan to substantially increase the capacity of small dams will be implemented through partnerships, which will bring benefits in terms of (i) creating jobs for locals (9 million workdays); (ii) improving the literacy of workers on construction sites; and (iii) training workers in construction trades such as masonry, iron framework, and the reinforcement, manufacture and application of concrete.

However, it should be noted that the construction of small dams hardly results in business opportunities: small dams require high upfront costs that pay back in the long run, therefore the initial costs are usually borne by society, rather than private investments.

Relevance for climate change adaptation. Water catchment increases drought resilience by keeping water accessible in periods with no or limited precipitation.

Application of the FAO Nexus Rapid Appraisal to biogas

Below, a closer analysis is performed for one critical technology for Morocco, biogas, on the basis of the FAO Nexus Rapid Appraisal, which is a desk-based application of the FAO Nexus Assessment. First of all, the following pressure and status indicators are chosen to describe the bio-economic pressure on each nexus aspect:

- Water indicators
  - Total internal renewable water resources per capita
  - Food produced per unit of water consumed
  - Fresh water withdrawal as a percent of total actual renewable water resources
- Energy indicators
  - Fossil fuel energy consumption
  - Net energy imports
  - Fossil energy intensity
- Land and food security indicators
- Labour indicators
- Cost indicators

They should be relevant for the technologies under analysis (biogas in this case). These indicators are then measured for Morocco, and compared with a benchmark (the global average) (Table 67).

97 Accessed January 2016.

Table 67: Selected nexus context indicators for Morocco relevant for the biogas technology

Water indicators	Total internal renewable water resources per capita (inhabitants/1 000 m³)	Food produced per unit of water consumed (m³/USD)	Fresh water withdrawal as a percentage of total actual renewable water resources (%)
Data source	AQUASTAT, 2016	Based on FAOSTAT, 2016 and AQUASTAT, 2016	Based on AQUASTAT, 2016
Reference year	2014	2014	2014
Morocco	0.063	0.76	35.7
Global (benchmark)	1.155	1.06	54.9
Divergence from benchmark	-98%	-28%	-35%
Corresponding bio-economic pressure (1 low to 3 high)	3.0	1.7	1.6
Weight assigned to the indicator (1 low to 3 high)	1	3	3
Resulting bio-economic pressure (1 low to 3 high)	1.9		

Energy indicators	Fossil fuel energy consumption (% of total energy consumption)	Energy imports, net (% of energy use)	Fossil energy intensity (kg of oil equivalent per $1 000 GDP [constant 2011 PPP])
Data source	World Bank WDI, 2016	World Bank WDI, 2016	World Bank WDI, 2016
Reference year	2012	2012	2012
Morocco	89.3	91.2	73
Global (benchmark)	81.3	-3.3	108.7
Divergence from benchmark	+10%	+2 864%	-33%
Corresponding bio-economic pressure (1 low to 3 high)	2.1	3	1.7
Weight assigned to the indicator (1 low to 3 high)	3	2	2
Resulting bio-economic pressure (1 low to 3 high)			2.2

Food indicators	Net import of agricultural products (total import value) / gross production value of agriculture PIN (ratio)	Average dietary energy supply adequacy (%) (3 year average)	Arable land per gross production value of agriculture (ha/$1 000 GDP [constant 2011 PPP])
Data source	FAOSTAT, 2016	FAOSTAT, 2016	FAOSTAT, 2016
Reference year	2013	2014–2016	2013
Morocco	0.352	123	0.83
Global (benchmark)	0.366	144	0.56
Divergence from benchmark	-4%	-15%	+48%
Corresponding bio-economic pressure (1 low to 3 high)	2.0	2.1	2.5
Weight assigned to the indicator (1 low to 3 high)	1	3	2
Resulting bio-economic pressure (1 low to 3 high)			2.2

Labour indicators	Unemployment (% of total labour force)	Total economically active population in agriculture / total economically active population (ratio)	Employment distribution / wage employment distribution in agriculture
Data source	World Bank WDI, 2016	FAOSTAT, 2015	FAOSTAT, 2016
Reference year	2014	2013	2012
Morocco	10.2	0.23	3.16
Global (benchmark)	5.9	0.39	3.13
Divergence from benchmark	+73%	-39%	+1%
Corresponding bio-economic pressure (1 low to 3 high)	2.7	1.6	2.0
Weight assigned to the indicator (1 low to 3 high)	1	3	3
Resulting bio-economic pressure (1 low to 3 high)	1.9		

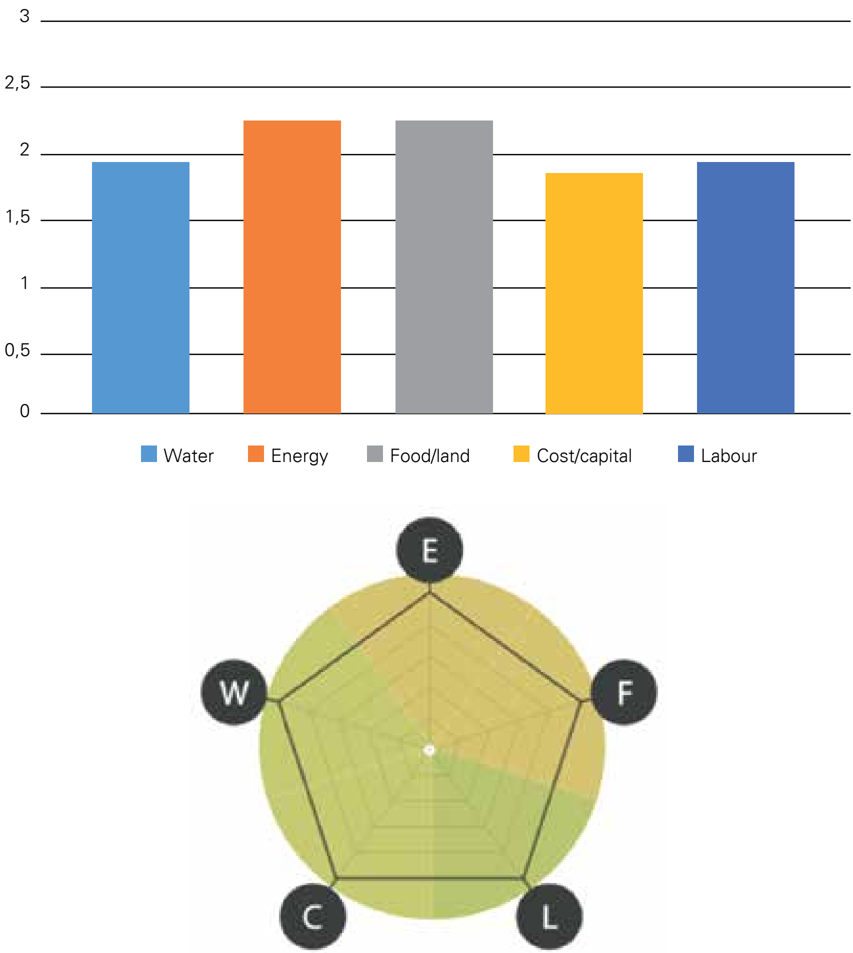
Cost/capital indicators	Gross capital formation (% of GDP)	Total economically active population / net value of agricultural produce	Gross national income per capita ($ [constant 2011 PPP])
Data source	World Bank WDI, 2016	FAOSTAT, 2015	World Bank WDI, 2016
Reference year	2013	2013	2014
Morocco	34.7	1.48	7 290
Global (benchmark)	22.3	1.34	14 931
Divergence from benchmark	+56%	-10%	-51%
Corresponding bio-economic pressure (1 low to 3 high)	1.4	1.9	2.5
Weight assigned to the indicator (1 low to 3 high)	3	2	1
Resulting bio-economic pressure (1 low to 3 high)			1.8

Source: Authors' compilation.

On the basis of the indicators selected and the analysis above, the resulting bio-economic pressure of Morocco on the 5 nexus aspects considered is reported in Figure 38. The results show a slightly lower pressure than the benchmark on cost/capital aspects of the nexus, followed by water and labour, and higher pressure on energy and food aspects. Indeed, although water is relatively scarce in Morocco by global standards, the analysis shows that the country as a whole has less pressure on water resources due to slightly higher efficiency usage rates relative to the global average. However, the pressure on energy resources is relatively high mainly because the country relies heavily on fossil fuels, which are largely imported. The pressure on food is also relatively high mainly because, according to the indicators chosen, the value added by agricultural production per unit of land is low.

However, all nexus aspects do not diverge significantly from the global average, which was used as a benchmark, meaning that there is no nexus aspect that stands out in Morocco because of high bio-economic pressure, according to the indicators chosen.

Figure 38: Results of the nexus context assessment for Morocco, following the FAO Nexus Rapid Appraisal



Source: Authors' compilation.

Note: Absolute values (1 to 3) are on the top and represented as background colours of the radar chart on the bottom (green=low pressure, yellow=average pressure, red=high pressure).

The analysis moves now to assessing the specific biogas intervention and the resulting resource use efficiency, before and after the intervention. For biogas, the following indicators are measured (and the weight assigned to each, from 1 to 3, is reported in parenthesis):

Water

- Water footprint of energy production when wastewater is used for feedstock mix (3)
- Water footprint of energy production when freshwater is used for feedstock mix (3)

Energy

- Contribution of RE to total electricity supply (3)
- Dependence on energy imports (2)

Land/food

- Yield increase by digestate versus slurry fertilisation (2)
- Arable land / gross production value (3)

Costs/capital

- Average cost of electricity produced (3)
- Cost of crop fertilisation (1)

Labour

- Wages (3)
- Hours of human activity / energy generated (2)

Table 68: Selected nexus intervention indicators for Morocco relevant for biogas technology

Biogas intervention	Water footprint of energy production in case wastewater is used for feedstock mix	Water footprint of energy production in case freshwater is used for feedstock mix	Contribution of renewable energy to total electricity supply	Dependence on electricity imports	Yield increase by digestate vs slurry fertilisation[98]	Arable land / gross production value
Biogas technology	795 m^3/gj	0 m^3/gj	100%	0%	74%	1 000 ha / current million USD
Benchmark	0.1 m^3/gj (natural gas)	0.1 m^3/gj (natural gas)	13%	85.4%	71%	
Divergence from benchmark	+1 110%	-∞	-750%	-∞	+4%	0%
Efficiency of resources use	5.0	1.0	1.0	1.0	2.9	3.0
Weight assigned to the indicator (1 low to 3 high)	3	3	3	2	2	3
References	UNESCO, 2008 Aderee, 2012	UNESCO, 2008 Sgc. 2012	IEA, 2016	MEM, 2012	Crop Research Institute, 2015	FAOSTAT, 2016
Resulting intervention score	3		1		2.9	

98 We assumed the use of cattle manure digestate and of cattle slurry on unfertilised winter wheat, yielding 5.68 t/ha.

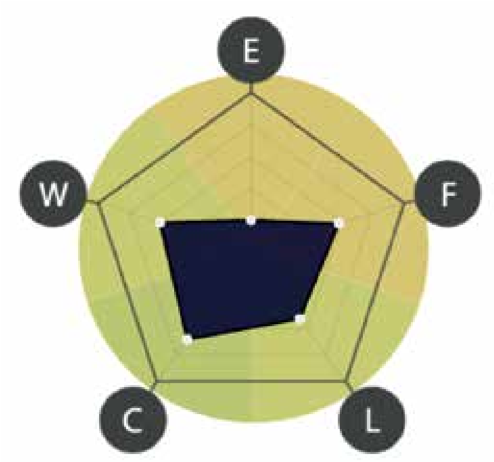
	Average cost of electricity produced	Cost of crop fertilisation	Wages	Hours of human activity / energy generated
Biogas technology	USD 0.15/kWh[99]	USD 180/ha/year (digestate as fertiliser)[100]	USD 1.3/h	1 h/kWh
Benchmark	USD 0.10/kWh	USD 422/ha/ year (synthetic fertiliser)	USD 0.8/ha	0.008 h/kWh
Divergence from benchmark	+50%	-57%	+62%	+12 400%
Efficiency of resource use	4.0	1.85	1.76	5.0
Weight assigned to the indicator (1 low to 3 high)	3	1	3	2
References	Ren21, 2015 Fraunhofer, 2013	Elmolight 2013	Based on the minimum wage in the agricultural sector and the minimum wage in non-agricultural sectors in Morocco	Diaz-Maurin & Giampietro, 2012 FNR, 2012
Resulting intervention score		**3.4**		**2.6**

Source: Authors' compilation.

99 Levelled cost of energy for biogas. Since no commercial biogas production from residues was found in Morocco, the global range of USD 0.06-0.235/kWh was used and a mean value estimated.

100 The field test conditions for synthetic fertiliser were: 550 kg/ha synthetic fertiliser (~270 kg NPK agent) for the total cost USD 476/ha (USD 390 purchase price, USD 8 transportation, USD 30 application, USD 48 plough-in cost) against 9 tonnes/ha digestate compost with similar NPK content, for the total cost USD 202/ha (USD 90 purchase price, USD 26 transportation, USD 38 application, USD 48 plough-in cost), resulting in a 42 percent cost savings.

Figure 39: Results of the Nexus Rapid Appraisal applied to biogas technology in Morocco



Source: Authors' compilation.

The results show that biogas production can have an important impact on water resource use compared to conventional energy generation, unless it is produced in conjunction with wastewater treatment. It also adds pressure on the cost/capital aspect of the nexus. On the labour aspect, the overall efficiency of using the resource workforce would be positive since much more human activity is needed to produce energy through biogas, but this is outweighed by the fact that people employed would be paid at higher wages than in agriculture (on the basis of the weights assigned to each criterion). However, the use of the fossil energy resource would end up being much more efficient than the alternative considered, because biogas would provide a solution to increase the RE generation share and reduce fossil fuel imports, thus decreasing the pressure of energy import dependence in the sector. It would also slightly improve the bio-economic pressure on the food aspect since the use of the resulting digestate can potentially improve the efficiency of crop fertilisation.

The analysis does not signal any clearly unsustainable effect of biogas on the WEF nexus, since the five nexus aspects are not particularly under pressure in Morocco, and the technology does not have an important negative impact on resource use efficiency other than water use efficiency, when biogas production relies on freshwater alone.

Results of Step 3

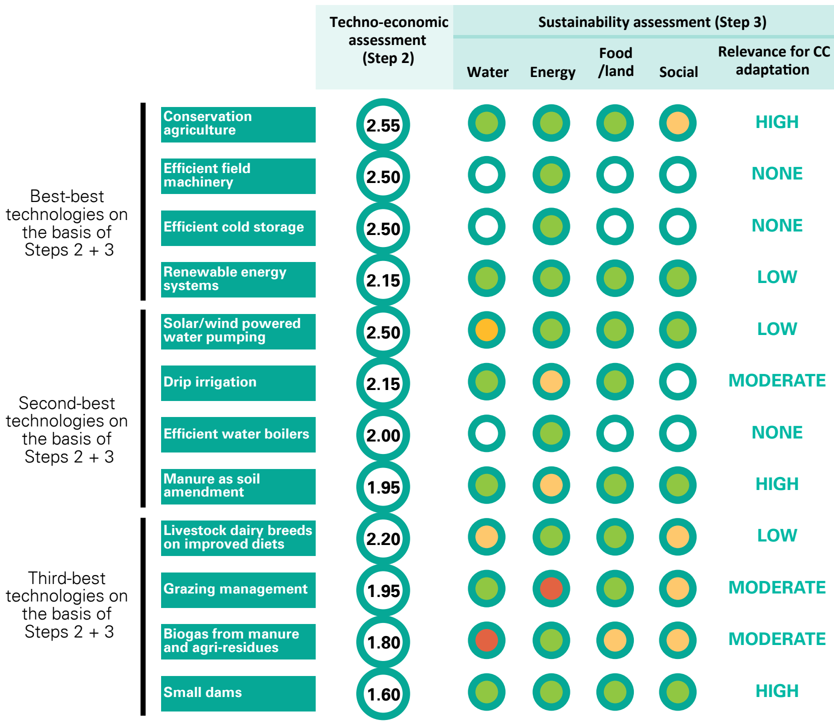
Step 3 identifies and assesses relevant sustainability issues linked to the selected technologies and practices to complement the techno-economic assessment undertaken in Step 2.

According to the application of the FAO Nexus Rapid Appraisal to the biogas technology, the most critical in terms of possible negative impacts on sustainability, this technology can significantly improve the bio-economic pressure on energy at the expense of limited additional pressure on the cost aspects of the nexus. The effects on the water component of the nexus (which is not under particular pressure in Morocco) can be significant in the case of biogas production from agri-residues due to the additional amount of freshwater consumption, while it would lead to a more efficient use of water resources if wastewater is used. At any rate, besides these limitations, biogas from agri-residues performs poorly from a techno-economic perspective in the country, making its potential market development low in Morocco among the technologies and practices considered.

It is clear that, while certain technologies and practices such as CA, manure as soil amendment, RE systems, small dams and the "energy efficient technologies" perform particularly well in Step 3 (they have either high relevance for CCA with minor sustainability concerns, or low relevance for CCA with no sustainability concerns), others such as drip irrigation, solar/wind-powered pumping, grazing management and biogas are expected to be limited in their market development by sustainability constraints.

Considering the results of Step 2, CA, efficient field machinery, efficient cold storage and RE systems could be considered "best-bet" technologies in the Moroccan context, meaning those technologies that perform well both from a techno-economic and sustainability point of view. They are followed by solar/wind-powered water pumping, drip irrigation, efficient water boilers and manure as soil amendment ("second-best" technology group). Livestock dairy breeds on improved diets, grazing management, biogas and small dams on the other side are expected to be less interesting in terms of market potential. The combined results of Steps 2 and 3 are shown in Figure 40. The analysis does not result in one single score, but the interpretation of results is expressly left to the assessor. In Step 4, specific barriers still hindering the market development of these technologies will be discussed and assessed.

Figure 40: Summary of results of Steps 2 and 3 of the methodology



Source: Authors' compilation.

Note: Technologies/practices are grouped as follows:

Best-bet technologies = (good techno-economic performance and minor sustainability concerns), (high relevance for CC adaptation) or (no sustainability concerns)

Second-best technologies = (good techno-economic performance and minor sustainability concerns) or (moderate techno-economic performance and no sustainability concerns)

Third-best technologies = (low techno-economic performance and no or limited sustainability concerns) or (sustainability concerns)

Step 4: Addressing barriers hindering uptake

The key objective of Step 4 is to identify thematic policy areas that may warrant greater attention to promote or improve adoption of sustainable climate technologies in the agrifood sector. Fostering the adoption of new technologies and practices relies, among other factors, on a conducive institutional and legal framework, which encompasses regulatory and legislative acts, financial support and implementation structures[101]. Morocco has recently implemented important steps to reduce investment barriers for climate-smart technologies and practices. However, several key issues still merit further examination. Step 4 therefore analyses relevant policies and institutional barriers and support mechanisms that influence the potential deployment of climate technologies and practices for GHG reduction in the Moroccan agrifood sector.

This section builds on the results from Steps 2 and 3 by drawing on the techno-economic analysis and assessment of sustainability aspects to identify important barriers to the adoption of specific technologies. In addition, it brings an extra dimension to the report by describing key policies that may impact policy adoption and concludes with the key thematic areas that may deserve more attention from policymakers. It would be too ambitious in an exercise as rapid as a four-step assessment to provide detailed policy guidance; moreover, policy formulation is often more successful when different stakeholders are involved and reforms are carefully assessed and debated. The objective of this process is therefore limited at identifying policy themes and directions that can eventually be further developed by Moroccan policymakers to support the deployment of climate technologies in the agrifood sector.

This section of the report is organized as follows: it begins by providing an overview of the policy and institutional setting in the Moroccan agrifood sector. The overview examines government initiatives to promote agricultural development and reduce GHG emissions, ranging from reforms to the launch of new programmes to support state objectives. It concludes with a brief discussion of potential barriers that could adversely impact the realisation of government goals in the sector.

Step 4 also investigates impacts of past policies on increased market penetration of technologies to see if there is an evident correlation between the

101 This framework can be supported by promotional measures, communications campaigns and proximity policies on training, R&D, and awareness raising around climate issues.

two. It focuses on the relationship between the market uptake of a technology or practice and relevant policies that may have had an impact on it.

This section then addresses barriers for each technology in three parts:

- Part 1 – *Diagnostics: policies and institutions* focuses on:
  – specific policies that may impact the adoption of the analysed technologies;
  – how these policies are implemented on the ground;
  – how different strategies and targets interact with financial, trade or policy incentives; and
  – the institutional setup behind each technology and other relevant social, market and economic issues that may affect its uptake.

- Part 2 – *Barriers and risks* builds on the conclusions from Steps 2 and 3 by identifying potential barriers and risks to the adoption of each technology. Different types of barrier have been selected by theme (see Table 69), ranging from knowledge and information gaps to access to credit and its cost, and are then given a qualitative score (from one star indicating a major barrier to three stars, not a major barrier) to indicate the degree to which the constraint limits uptake. For example, the limited presence of support services and structures is perceived as a major barrier to the implementation of CA, while the financial returns from uptake are seen as an incentive for adoption. Moreover, this section also seeks to identify if barriers may impact certain potential adopters relative to others. For example, credit constraints may affect some farmers seeking to adopt climate technologies and not others. Finally, the section draws on the results from Steps 2 and 3 to indicate any risks (in particular Step 3's environmental and sustainability issues) that may need to be addressed or taken into consideration when developing support policies.

Table 69: Guidance on typology of key barriers

Knowledge and information	Organization/ 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 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	Are low returns a barrier and if so, in which cases? IRR, payback as per Step 2	Credit market failures Is upfront investment cost very high? Cost of capital too high

Source: Authors' compilation.

- Part 3 – *Key instruments and drivers* suggests which thematic policy areas may be interesting for further exploration. It starts by exploring the track record and impact of past policies implemented to encourage technology adoption insofar as possible given the difficulty in establishing exact causal links. It then offers suggestions for potential policies, instruments and drivers that may help policymakers overcome the aforementioned barriers and risks. This last part concludes by assessing the expected "policy reform intensity" for each technology. This provides a very rough evaluation of which technologies would require the biggest changes to current policies and/or the largest public support measures (including financial allocations) to support adoption.

Overall policy and institutional setting in the country

The Moroccan government has prioritised both the promotion of the agricultural sector and the reduction of GHG emissions at the national level, demonstrating its interest in enhancing sustainable agricultural development. These priorities have guided a number of initiatives and reforms at the regulatory, institutional and economic levels. However, a number of barriers remain that may hinder the achievement of government goals.

Supporting agricultural development

As a major source of export revenues and employment, agriculture is an important sector for the Moroccan economy. Since the early 2000s, Morocco has taken significant steps to liberalise the country's agricultural trade and reform the agricultural market, leading to the signing of two free trade agreements with major agricultural trade partners: the United States and the European Union. While these agreements have expanded access to key markets for Moroccan agricultural exports, they have also opened the domestic market to imports and reduced the degree of protection given to domestic producers.

Most importantly, to further the development of the sector, diversify agricultural activities and increase value addition – namely through processing and marketing – the Government of Morocco's 2008 PMV includes two key pillars. First, the PMV seeks to support the establishment of high value added, highly productive farming systems and agro-industries that are internationally competitive. Within this, the state aspires to boost cereal productivity due to the strategic importance of the crop in the Moroccan diet, while selectively protecting key agricultural subsectors where the country has a comparative advantage[102]. To sustain this pillar, the government allocated MAD 70 billion to improve productivity rates amongst 560 000 farmers[103]. This has already reaped results: the agricultural value added increased from MAD 70 billion in 2008 to MAD 105 billion in 2014, representing an increase of 50 percent, the highest average annual growth rate in the economy. Agricultural exports have also increased 34 percent since 2008, benefiting from a 170 percent increase in agricultural investments between 2008 and 2014. By 2020, the government aims to achieve additional targets such as the doubling of investments in downstream agricultural activities and the rationalisation of irrigated land to increase profitability to over MAD 4 000 per hectare.

The second pillar aims to relaunch traditional agriculture in disadvantaged regions. This pillar is designed to address socio-economic inequalities and reduce poverty by boosting the incomes of small- and medium-sized farmers, particularly in peripheral and marginalised regions. An estimated MAD 20 billion in investment has been earmarked to support 840 000 farmers achieve this objective through the launch of 545 projects to reinforce and professionalise small farms by 2020. During that time, the MAPM also aims to double revenues for projects in small-scale farming and establish 10 000 new agricultural cooperatives.

The two pillars of the PMV are accompanied by other actions related to (i) the mobilisation of finance in a PPP framework; (ii) the improvement of market access to wholesale markets and slaughterhouses; and (iii) the promotion of water-saving technologies in irrigation with specific targets. For example, regarding the last theme, given the increasing occurrence of droughts and the scarcity of water resources, the PMV aims to incentivise the adoption of drip irrigation systems to reduce the use of surface irrigation. More broadly, the

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102 Including olives, fruit and vegetable exports.

103 This pillar is defined around 5 criteria: improving performance; promoting inclusive agriculture; boosting international competitiveness; fostering sustainable and environmentally friendly agriculture; and putting in place an agricultural system that increases the availability of quality products.

PMV seeks to mobilise MAD 10 billion annually for the agricultural sector by 2020 through improvements to the investment climate in the sector while fixing specific objectives at the macroeconomic, regional and value chain levels[104].

The work of the PMV has been complemented by initiatives within a number of government ministries. In 2010, the Ministry of Industry, Trade, Investment and the Digital Economy launched the "Industrial Emergence" (*Émergence industrielle*) programme to encourage investments in strategic sectors for the future, notably in agribusiness, and provide support for access to land, markets, credit, and necessary services such as transport and communications. Particular emphasis has been made to support sectors with high export potential, particularly in the processing of fruit and vegetable products, as well as olive, argan, spices and aromatic and medicinal plant products. Meanwhile, the National Pact for Industrial Emergence (*Pacte National pour l'Émergence Industrielle*) was conceived to support national meat and milk production, while improving the performance of current market participants[105]. Having signed the OECD declaration on green growth in May 2012, Morocco is a leading country in the region in promoting sustainable development, particularly in the field of RE generation[106]. Morocco is also partner to a number of agreements in agriculture, including a tripartite agreement with Swaziland and FAO to receive technical assistance in agricultural development and food security[107].

The PMV acknowledges the presence of constraints facing the agricultural sector in Morocco, which are also important in terms of technology adoption, namely land tenure and associated size of farms, fragility of the private sector and conflicting state initiatives. Moreover, according to the National Federation of Agribusiness (*La Fédération Nationale de l'Agroalimentaire*, FENAGRI, 2016), additional barriers that may slow the development of the agribusiness sector and in particular technology adoption include delays and difficulties in the implementation of new sector regulations and activities in the informal sector,

104 This approach has led to the establishment of 18 programme contracts between the state and inter-professional organizations.

105 The objectives are: (i) to increase the existing processing capacity of players in cattle farming and milk production; (ii) improve slaughtering practices and develop modern distribution in the meat industry; and (iii) support the creation of large integrated projects.

106 For more information, refer to Steps 1 and 2.

107 For information on other agreements, please refer to Fellah Trade (2015) and Ismaili (2016).

which create unfair competition for formal sector participants and limited access to innovation and R&D[108].

Encouraging GHG emission reductions and sustainable production

Regarding sustainability and the environmental footprint of the agricultural sector, Morocco has set ambitious targets to reduce its GHG emissions and has already made significant efforts to reach them. In particular, the country has developed a set of strategic documents to guide its efforts in ensuring greater sustainability and setting the basis for a greener economy. Some of these documents are also extremely relevant for the agrifood sector: the National Sustainable Development Strategy (*Stratégie Nationale de Développement Durable* [SNDD] [2015–2020]), the National Water Strategy (*Stratégie Nationale de l'Eau* [2009–2030]) and the National Energy Strategy (*Stratégie Nationale Énergétique* [2008–2030]) all put a clear emphasis on sustainable production and efficient management of natural resources. As previously mentioned, the country is a signatory to the OECD Declaration on Green Growth and is a leader in the region in terms of sustainable development, as exemplified by the initiatives laid out in the third National Communication of Morocco on the Convention Framework of the United Nations on Climate Change (*3ème Communication Nationale du Maroc à la Convention Cadre des Nations Unies sur le Changement Climatique*). To promote these objectives, Morocco has established a diversity of new institutions, such as ADEREE and the MASEN, which are discussed in more depth later in the section.

In 2015, Morocco developed an intended nationally determined contribution (INDC) under the UNFCCC, which builds on the SNDD and aims to achieve a cumulative reduction of 401 $MtCO_2eq$ from 2020–2030. Agriculture, water, waste, forest and energy are among the main areas of intervention. In particular, the INDC covers emissions related to energy demand by agriculture, enteric fermentation and manure management, cropping systems and land-use for agriculture (cultivated soils). Climate sustainable strategies have also been discussed and adopted by several Ministries and Agencies, such as the MAPM, MEM and the National Electricity Office (ONE). These programmes have been complemented by the work of international financial institutions (IFIs) such as the World Bank, which supports a number of related projects through the Climate Change Adaptation Programme. The aforementioned initiatives have paved the way for the 22nd United Nations Climate Change Conference (COP22) held in Morocco in November 2016.

108 The issue of limited access to innovation and R&D drew support from the Ministry of Industry, which worked to create a favourable environment for innovation based on two programmes: INTILAK and TATWIR. The first programme targeted new start-ups with potential for development that operate in the industrial sector or advanced technologies, and finances up to 90 percent of expenses within the first 2 years of the project, with a maximum of 1 million MAD (USD 100 000). The second is for R&D and innovative projects, and covers a maximum of MAD 4 million (USD 400 000), or 50 percent of expenditure on R&D. For more information, see: MICEN. 2012. Communiqué de presse. http://www.cmi.net.ma/INTILAK.html and http://www.cmi.net.ma/TATWIR.html.

The Moroccan government has taken steps to adjust state financial incentives to reduce GHG emissions. Between late 2013 and 2015, government subsidies for gasoline, fuel oil, diesel fuel, and fuel used for electricity generation were eliminated. However, the impact of these fiscal measures on energy consumption cannot be easily measured since they were adopted recently and coincided with an international drop in basic commodity prices. Despite these reforms, high subsidy levels remain in place for butane (bottled gas), since it represents a socially sensitive issue. The butane subsidy cost the state an estimated MAD 13.2 billion in 2014[109] as it represented over 100 percent of the selling price, and this high level of price support has translated into significant consumption in the agricultural sector despite the fact that the use of subsidised butane for non-domestic uses such as agriculture is illegal (IFC, 2014). Butane remains one of key remaining products that are subsidised through the government via the Moroccan Compensation Fund (*Caisse de Compensation*).

Reducing agricultural risk while enhancing access to credit

A number of financial mechanisms are in place to support and protect agricultural investments. For example, the PMV is supported financially by the CAM, which created several financial products designed to encourage the modernisation of farms and service companies in rural areas (IFC, 2014). In particular, the SAQII credit fund aims to finance modern irrigation schemes (IFC, 2014). Additionally, the MAPM put in place funds to provide insurance products for drought in 1994; while in 2011, the Moroccan Agricultural Insurance Mutual (*Mutuelle Agricole Marocaine d'Assurance* [MAMDA]) began offering the "multi-risk climate" insurance, primarily for cereal and legume production, and subsequently for arboriculture[110]. In 2016, the state dedicated MAD 4.5 billion to fight against the effects of drought, as well as an additional MAD 1.25 billion for potential compensation in multi-risk climate insurance for cereal and spring crops (MAPM, 2016).

Other financial incentives that may drive technology adoption in Morocco include promoting agricultural products exports, equipment incentives (in the case of direct sowing, irrigation and some wind machines), and processing units to develop the agrifood sector (MAPM/FDA, 2015a). Incentives also exist to encourage cooperation in marketing, production, and other related activities to promote economies of scale, including *agrégation*, which functions as a partnership between producers and marketers/industrial actors. The incentive provides a 100 percent subsidy to establish wells, drillings, water reservoirs, irrigation materials and connections, automation gear and other related tasks (MAPM/FDA, 2015b).

109 See: http://www.medias24.com/ECONOMIE/ECONOMIE/157152-Exclusif.-Le-gouvernement-supprimera-la-subvention-du-sucre-en-2016.html.

110 In 2014, 718 000 hectares were insured.

Associating impact of past policy interventions on technology adoption

As described in the methodology, a separate analysis in this step looks to identify a correlation between the market uptake of the technologies under examination and relevant policies that may have had an impact on it. For example, the uptake of solar water pumping among farmers can be directly impacted by a range of factors, such as incentives for RE off-grid production, the introduction of a new regulation on maximum water withdrawal from underground aquifers or a change in fossil fuel subsidies, which will dictate in part the market development of this technology.

The main limitation in this analysis is associated with the absence of good historical trends for market indicators for the technologies considered and the difficulty in establishing causality. Table 70 summarises the first choice market indicator for each technology following the methodology document, as well as second choice indicators that have been employed to provide a historical evolution of technological uptake, as well as their source[111]. These same indicators should be used to assess the two market criteria – "current technology adoption rate" and "trends in gap between current technology uptake and technical potential". However, in cases where information availability did not allow for the best indicator or proxy for both criteria, the best available indicator or proxy was used for the first criterion and another proxy was chosen for the second according to trend data availability.

111 Market penetration is assessed by dividing these indicators by the total market potential (e.g. hectares under CA/total arable land with potential for CA adoption, number of improved livestock dairy breeds/total number of dairy cows).

Table 70: First choice and actually measured indicators to monitor market penetration of selected technologies and practices

Technology or practice	First choice market indicator	Measured market indicator or proxy indicator	Source
Conservation agriculture	Hectares under CA	Hectares under CA	NOVEC, 2013 and discussions with local experts and practitioners
Efficient field machinery	Number of efficient tractors sold and/or inspected	Number of tractors less than 5 years old	AMIMA et IAV Hassan II, 2014 & MAPM, 2011
Drip irrigation	Hectares under drip irrigation	Hectares under drip irrigation	MAPM, 2015a
Solar/wind-powered water pumping	Number of wind/solar pumps sold	Number of solar pumps in use	IFC, 2015
Grazing management	Hectares of land managed	LU under improved practice	IFAD, 2002a
Manure as soil amendment	Sales of systems for improved manure management	Amount of organic residues treated into compost and/or Volume of manure under improved practices.	Local experts
Livestock dairy breeds on improved diets	Number of improved/ pure livestock dairy breeds with improved diets	Number of improved livestock dairy breeds (potential to improve diets) and number of LU in irrigated dual purpose farms (potential to improve breeds and diets)	FAOSTAT, 2015; DDFP/MAPM, 2015
Efficient water boilers	Sales of efficient boiler capacity in the agrifood sector	Number of water boilers in use in the food industry	Local experts
Efficient cold storage	Installed energy efficient food storage capacity	Installed energy efficient food storage capacity	IARW, 2014 and local experts
Biogas from agri-residues	Volume of biogas produced from agri-residues	None because the technology has not been adopted	MAPM and local experts
Renewable energy systems	Renewable energy generation (Wh) in the agrifood sector	Renewable energy generation (Wh) in all sector	IEA/IRENA 2015
Small dams	Million m^3 of mobilised water	Million m^3 of mobilised water	AQUASTAT; literature review

Source: Authors' compilation.

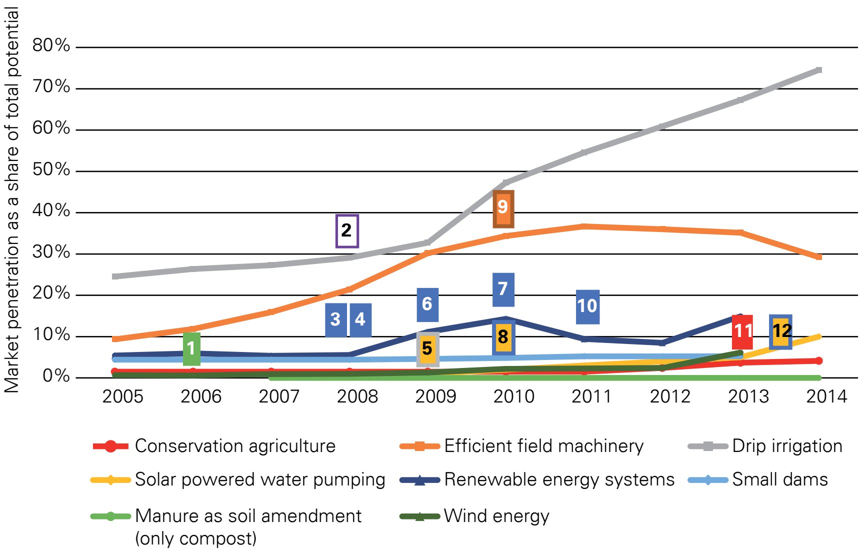
The trends in market penetration estimated for the selected indicators are plotted in Figure 41 for the period 2005–2014, highlighting changes in terms of technology/practice uptake over time. Those technologies for which only one or two observations existed were removed from the analysis, since they would have resulted in a linear trend or spot observations, which are not useful for this analysis. The technologies for which a historic trend could not be drawn include food cold storage and water boilers in the food industry, although for the latter technology, a registry of all industrial boilers in the country should be available at the government level. However, the data obtained within the timeframe of the analysis were not sufficient to estimate a trend line for this technology. This also applies to area under improved grazing practices and improved livestock breeds, for which no trend can be estimated due to the lack of data.

The trends are then analysed vis-à-vis the relevant policy or regulatory measures which were introduced and could have had an impact (positive or negative) on the market development of the technologies. The relevant policy interventions reported in Figure 41 are explained in the table below it, together with their year of implementation, policy type and an indication of the technology/practice that they are expected to impact[112].

The analysis performed is not meant to identify any causality between the adoption of a technology and a single policy, since the market development is normally the effect of a number of factors often lying outside the policy actions or the national context (e.g. falling international prices of PV modules can have a direct effect on the adoption of PV pumps), but rather to have a joint summary of markets trends and related policies that may suggest opportunities for analyses of policy interventions.

112 Policies adopted or implemented after 2014 are excluded from the analysis since they can have no impact on the trends.

Figure 41: Adoption of technologies and practices over time vis-à-vis relevant policy or regulatory measures introduced in Morocco, 2005–2014



	Policy	Year of implementation	Policy type	Technology / practice relevance
1	Law 28-00 from 2006 managing agricultural waste disposal and treatment	2006	Policy support	Manure as soil amendment (only compost)
2	PMV and related measures: Crédit Agricole of Morocco Programme National d'Économie d'Eau d'Irrigation (PNEEI) Programme d'Extension de l'Irrigation (PEI)	2008	Policy support Institutional creation Financial supports Modernisation of farms Economic instruments Service companies in rural areas	All (except cold storage, efficient boilers, RE systems)

3	Law of self-generation (Law 16.08)	2008	Policy support Institutional creation Voluntary approaches (unilateral commitments by private sector)	RE systems
4	National Energy Strategy (Stratégie Nationale Énergétique [2009–2030])	2008	Policy support	RE systems
5	National Water Strategy (Stratégie Nationale de l'Eau [2009–2030]}	2009	Policy support	Drip irrigation Solar power for water pumping
6	Renewable Energy Development (Law 13.09)	2009	Policy support Technology deployment and diffusion	RE systems
7	National Agency for the Development of Renewable Energy and Energy Efficiency (ADEREE) (Law 16.09)	2010	Policy support Institutional creation	RE systems
8	National Integrated Project for Solar Electricity Production & MASEN (Law 57.09)	2010	R&D programme Technology deployment and diffusion Institutional creation Economic instruments Policy support	Solar power for water pumping RE (solar systems)
9	Law 52.05 & implementing Decree No. 2-10–421 & decrees relating to vehicles	2010	Policy support	Efficient field machinery
10	Energy Efficiency (Law 47.09)	2011	Policy support Economic instruments	RE systems
11	Subsidy for purchases of direct seeding equipment	2013	Economic instruments	Conservation agriculture
12	Elimination of subsidy on gasoline, fuel oil, fuel used for electricity generation	2013–2014	Economic instruments	Solar/wind-powered water pumping RE systems

Source: Authors' calculations.

Note: (i) For drip irrigation the numerator is the total number of hectares under drip irrigation reported by the MAF (e.g. 410 000 ha for 2014) whereas the denominator is the target set by the PNEEI/PMV of 550 000 hectares. Hence the near achievement of the adoption potential; (ii) for efficient tractors, the adoption rate is estimated to be the share of tractors below 5 years; (iii) RE adoption is reported in terms of the share of electricity produced each year from hydropower and wind; (iv) the remaining technologies use the market size and adoption as clearly indicated in Step 2.

The analysis highlights that RE production (the graph includes only wind and hydropower electricity generation as there were not available data for electricity generation from solar energy) has been increasing significantly in Morocco since 2008, the year when the national energy strategy and the law on self-generation were implemented. The drop in 2008 and 2009 is caused solely by a decrease in the generation of electricity from hydropower and not by a decrease in installed generation capacity. Wind energy-generated electricity in particular increased almost fivefold from 2009 (391 GWh), the year of the implementation of the Renewable Energy Development law to 2013 (1 841 GWh). PV energy may have followed a similar development.

Solar water pumping started being adopted in 2009, after the introduction of the National Water Strategy until 2030. The market penetration of this technology is further supported by the introduction in 2010 of the National Integrated Project for Solar Electricity Production, of the National Agency for Solar Energy and the MASEN and the establishment of ADEREE, as well as the elimination of subsidy on gasoline, fuel oil, fuel used for electricity generation in 2013. In 2014 there were 16 500 solar water pumps in the country according to IFC.

The market penetration of drip irrigation shows a significant increase after the introduction of the PMV. As mentioned before, this plan includes a number of policies which had and are having an impact on the whole agricultural sector in Morocco, far beyond the single technologies analysed here. However, looking at the PMV as a single package originally introduced in 2008, it appears that there may be also a positive correlation between the PMV, the market penetration of solar water pumping and the introduction of new (efficient) tractors (to support the development of the agricultural sector set by the PMV). On the other hand, no apparent correlation can be found between the introduction of the PMV and CA, or with the production and use of compost. In the same way, the 2006 law on the management of agricultural waste disposal and treatment has had no evident impact on the compost production and use in the country.

It is too early to find a correlation between the introduction of a subsidy to purchase direct seeding equipment and the area under CA. It seems that a positive correlation exists, but this may be due to other factors such as the implementation of specific development projects, therefore an impact not led by this particular incentive. The specific barriers for each specific technology/practice still existing today and linked to regulation, incentives or public expenditure are analysed and summarised in the next section.

Key barriers, risks and possible solutions to overcome them by technology

This section is organized by technology and will provide a snapshot of existing policies and institutions that can impact adoption of each technology, barriers and risks to adoption (based on Steps 2 and 3) and key instruments and drivers for fostering adoption. The most relevant barriers or risks to adoption of a specific technology/practices according to the authors (on the basis of the information collected and discussions with local experts) are highlighted in bold in the relevant tables summarising the assessment of barriers and risks.

Conservation agriculture

Diagnostics: policies and institutions

Table 71: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• Targets recently announced under PICCPMV project • No mention in the national communication	• N/R	• 50% subsidy on direct seeders up to a maximum of MAD 90 000 started in 2013 • Trade and other policies resulting in price distortions may translate into lower incentives to rotations	• PICCPMV project has recently piloted the technology mostly with small farmers • Some indirect support through research programmes (INRA, IAV Hassan II)

Source: Authors' compilation.

The key institution dealing with CA in Morocco is the MAPM, given its overall mandate, particularly its interventions in agricultural extension and the key support policies embedded in the PMV. Within the MAPM, many institutions are of importance to CA including directorates concerned with production techniques, specifically cereals, legumes and oilseed crops. The regional agricultural directorates (*Directions Régionales de l'Agriculture*) and extension services (including development of messages and delivery of support services) and research and education institutions (such as INRA, ENA-Meknès and IAV Hassan II) also play an important role, namely through agronomic and other studies linked to the adaptation of conservation practices to the Moroccan context.

Overall, Morocco does not have clearly set targets in the number of hectares to be reached with CA practices. However, the technology has recently received more attention from policy-makers mainly through the implementation by MAPM/ADA of the PICCPMV project[113]. As indicated in Table 71, the evaluation report of the PICCPMV project indicated a target of 200 000 hectares with CA to be reached by 2025 in Morocco, although it is not clear whether this has become an official government target (as those in the PMV) with the ability to provide a strong signal to the private sector.

113 *Projet d'Intégration du Changement Climatique dans la Mise en œuvre du Plan Maroc Vert* (PICCPMV) – Integrating Climate Change in the Implementation of the PMV is a World Bank-supported project approved in 2011 and implemented by the Government of Morocco.

There have not been major regulatory reforms or regulations put in place in the case of CA, but the government has set direct price incentives to foster adoption, namely through equipment subsidies. This was started in 2013 and is still valid today as part of the support provided under the FDA: a 50 percent direct seeder subsidy up to a maximum of MAD 90 000. Normal seeders (simple or combined), as well as other planting equipment also receive a 50 percent subsidy but only up to MAD 48 000. All equipment subsidies are limited to one seeder per tractor (tractors are subsidised at 30 percent with a limit of MAD 72 000 per unit, with one tractor equal to at least 5 hectares). Other direct price incentive policies such as the ones affecting cereals, legumes and oilseed crops are also thought to have an impact on CA adoption because of their potential price signals to farmers and impact on rotations, which would be desirable as an important element of CA.

In addition to price incentives, the government has supported R&D activities since the 1980s, namely through INRA, ENA Meknès and IAV Hassan II. This includes funding tests of direct seeding at the regional agronomic research centre of INRA in Settat in collaboration with USAID. Finally, the government and the World Bank-supported PICCPMV project has piloted CA as a climate technology in several regions of Morocco on a total of around 3 000 hectares (about 65 percent of the total surface under CA in Morocco at present).

Barriers and risks

Table 72: Summary assessment of barriers and risks

Barriers						Risks
Knowledge and information	Organization/ social	Regulations/ institutions	Support services/ structures	Financial returns	Access/cost of capital	
• Lack of farmer knowledge about the technology is a major issue • Among early adopters, appropriate knowledge on technology use is a problem and can influence initial results and sustainability	• Direct seeder rental markets or alternatively farmers organized to share equipment would help adoption • Organization and social practices linked to livestock production do not favour maintaining crop cover	• N/R	• Repair shops exist for conventional equipment and can be adapted but are still not able to service direct seeders adequately • Direct seeders imported from abroad are heavy and not adapted to most local tractors	• Financially attractive • Cash flow profile in first years can be problematic depending on farmer knowledge • Rotations may not be incorporated by farmers due to price signals and value chain development constraints	• Upfront investment cost is high • Access to credit for poorer farmers can be problematic	• Possible increase in the use of herbicides in the short term can potentially have a negative impact on water quality

Source: Authors' compilation.

The technical and economic analysis in Step 2 suggests that the main barriers to adoption of CA in Morocco are primarily knowledge, information and the availability of an efficient network of support services. To some extent, financial returns and access to capital can play a role. The summary assessment is shown in Table 72. Regarding the key barriers, despite the pilot testing and research conducted, there is still generally a limited awareness about the technology and its benefits among Morocco's farmers. Moreover, pilot tests such as those in the PICCPMV have focused mainly on smallholders, while adoption by farmers in Morocco – albeit limited in extent – has been mainly by larger farmers. In addition to awareness, good knowledge of the technology is key and not easy to achieve without appropriate technical assistance. This is especially important as it can also impact the financial returns by avoiding initial drops in yields and consequently hinder adoption (especially by poorer farmers). Support structures in the country exist for traditional seeders and would need to be adopted. This is also considered an important barrier since farmers need a reliable network of support services for equipment maintenance and operation.

According to the analysis in Step 2, financial returns are attractive but cash flow profiles in the initial years can be an issue if farmers are not capable of adopting the technology correctly. The result is a dip in yields, which can deter adoption. Moreover, rotations that can have a significant positive impact on financial returns and sustainability of the technology are not easily practiced because of difficulties in commercialising produce (this is a problem at large scale for rotation with oilseeds for example), but reportedly also because of labour constraints (that impact returns on leguminous crops). Overall price incentives and supply chain constraints therefore create fewer incentives for including rotations in CA practices. Finally, access to credit for small farmers for equipment purchases even in the presence of subsidies may be a barrier to adoption, according to most evidence in the country.

The sustainability risks related to CA are minor as evidenced by the analysis in Step 3 and in fact CA can have a substantial impact on adaptation to climate change by creating conditions for greater yield resilience in the face of drought.

Key instruments/policies/drivers in the analysis above summarises relevant policy themes that could be interesting to develop further to support CA adoption in Morocco. The analysis suggests that a national target for CA adoption could be developed based on studies already conducted and to signal commitment to this type of farming technology. In terms of regulations, there does not seem to be the need for much reform; while on price incentives, the overall support policies could be reviewed in light of support to crop rotations for more sustainable farming practices. In particular, it is not clear whether the subsidy on buying equipment is necessary given the market dynamics and the high returns to investing in CA. Moreover, the rapid assessment suggests that more pilot programmes on CA, particularly with lead/larger farmers, could be important in overcoming barriers to adoption. Using funds toward capacity development of public and private extension services for dissemination of knowledge on CA technology will also be a useful step toward adoption. Finally, given the level of reform and budget allocations required (mainly in terms of supporting capacity development and pilot programmes), the policy reform intensity of supporting CA adoption in Morocco is deemed moderate.

Table 73: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• Can help to signal CA as a policy priority	• N/R	• Subsidy may not be required if support to rental market for direct seeders • Rebalancing of support policies can promote rotations	• Pilot programmes with lead/ larger farmers for demonstration • Capacity development of public extension and private extension support services	**

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

Efficient field machinery

Diagnostics: policies and institutions

Table 74: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• No official target announced although PMV promotes increased mechanisation	• Regulations setting limits on emissions	• 30% subsidy to purchase tractors with an upper limit of MAD 72 000 and maximum numbers of units according to surface in hectares (approximately one every 5 hectares) (MAPM/FDA, 2015a)	• One-stop shops to simplify applications • Some indirect support through research programmes

Source: Authors' compilation.

With the technical assistance of FAO, in 2011, Morocco devised a national strategy to mechanise the agricultural sector. The strategy employs state financial initiatives, the establishment of PPPs, and the dissemination of more efficient, environmentally sustainable production practices to forward this goal (MAPM, 2011). The mechanisation of Moroccan agriculture is primarily overseen by the MAPM, which has a number of offices and agencies that address different elements of the mechanisation process. Major offices include:

- The Strategy and Statistics Department (*Direction de la Stratégie et des Statistiques*)
- The Finance Office (*Direction Financière*; oversees subsidies and management of the FDA)
- National Office of the Agricultural Council (*Office National du Conseil Agricole* [ONCA]; offers agricultural advice to farmers)
- Directorate of Education, Training and Research (*Direction de l'Enseignement, la Formation et la Recherche*; provides technical education, higher education and research)

The legislation for agricultural motor machines rests within the Highway Law No. 52-05 and its application decree No. 2-10-421 which, in accordance with related decrees, outlines emission rates set by the Ministry of Equipment and Transport and the MEM. Within this, conditions have been determined for the emission of pollutants from compression ignition engines in agricultural and forestry tractors.

Over the last few years, the state has encouraged the mechanisation of agriculture through the provision of grants, subsidies and increased access to credit for farmers. For example, individual farmers are able to receive a 30 percent subsidy to purchase tractors, while groups of farmers are entitled to a 40 percent subsidy (MAPM/FDA, 2015a and 2015b). These subsidies are made available via a number of banking initiatives, particularly through the *Crédit Agricole du Maroc*. Additionally, since 2008, the MAPM has put in place one-stop shops in every regional office to respond to applications for subsidies and to simplify the application procedures for requesting financial aid. This has made the FDA implementation more efficient.

The mechanisation of agriculture is also encouraged through the promotion of technical training facilities such as the Institute of Agricultural Technicians Specialised in Mechanical Engineering and Rural Equipment (*l'Institut des Techniciens Spécialisés en Mécanique Agricole et en Equipement Rural*). A number of qualification centres also train workers and promote research in agricultural mechanisation, including the National Institute for Agricultural Research (*l'Institut National de la Recherche Agronomique*) and the Hassan II Agronomic and Veterinary Institute (*l'Institut Agronomique et Vétérinaire Hassan II*).

Other relevant policy-related topics for tractors include recent discussions to upgrade Moroccan tractors from Tier 2 to Tier 3 motors. In 2013–2014, the state was considering the promotion of this transition, which would bring Morocco more in line with the machines used in the European market. However, after discussing the transition with sector representatives, the government postponed the move due to the fact that Tier 3 machines cost around EUR 3 000 more per engine, thereby imposing financial constraints on Moroccan farmers[114]. However, this postponement is considered temporary due to the fact that Moroccan agreements with the European Union entail the progressive harmonisation in regulations, while in the medium term, only Tier 3 and later Tier 4 machines will be available in the European market[115].

Barriers and risks

Table 75: Summary assessment of barriers and risks

Barriers						Risks
Knowledge and information	Organization/ social	Regulations/ Institutions	Support services/ structures	Financial returns	Access /cost of capital	
• Lack of farmer knowledge about the technology and other fuel-saving practices	• N/R	• Limited institutional coordination	• Few testing benches for tractors	• Financial returns are low for tractors at the end of their economic lives, therefore this practice should be adopted up to 1 year before the end of the tractor's life	• Lack of access to credit • Maintenance costs may deter uptake	• N/R

Source: Authors' compilation.

Limitations in farmer knowledge serve as one of the two major barriers to the adoption of more efficient field machinery in Morocco. Although technicians are well informed on the practices required to improve energy consumption in field machinery, few farmers apply these in practice. As a result, considerable efforts must be made to effectively train and sensitise farmers to the benefits of effectively managing field machinery and performing motor tests to reduce fuel consumption.

114 Information obtained from interviews with importers of agricultural materials.

115 Currently Tier 4 vehicles are sold in the transport sector in Morocco.

At the same time, the deployment of more efficient farm technology is slowed by the relative scarcity of support services. Currently, there is a widespread availability of repair shops, however there are few fixed or mobile testing benches in Morocco, thereby limiting the ability of farmers to perform necessary tests to curb fuel consumption.

In contrast, financial returns pose a relatively small barrier to technological uptake; as mentioned in Step 2, savings garnered from reduced fuel consumption would yield attractive returns, provided that testing is performed until the 8th year of the tractor's life, assuming an economic life of 10 years[116]. This type of climate-smart technology becomes particularly attractive in light of the removal of key energy subsidies in the last few years. However, if farmers are not informed of the potential savings in fuel consumption, they may be initially discouraged from testing their tractors due to the inspection cost, which stands at around USD 500 per tractor. That said, according to the analysis conducted in Step 2, even with a cost of USD 500 per tractor, it would still be financially worth the investment to tune the engine until the 8th year of the tractor's economic life. Additionally, the standard cost in other countries such as France is closer to USD 130, therefore if the cost of inspection were subsidised, it could become more attractive to farmers. More broadly, upfront costs remain quite high for farmers, making the cost of capital the second major barrier to adoption.

Finally, the adoption of this practice would benefit from improved institutional coordination. Specifically, the establishment of regional committees to coordinate testing, provide guidance to farmers on maintenance and management, and other necessary functions would be useful to promote technological uptake.

Key instruments/policies/drivers to overcome barriers

Due to the limited availability and knowledge of motor testing services, there is considerable scope for expansion in Morocco. Additionally, the recent removal of key energy subsidies will likely incentivise farmers to curb fuel consumption, thereby increasing the appeal of motor tuning and other consumption-saving measures. However, consumer demand for these measures has not yet grown to its potential due to low energy prices in international markets.

To harness the sustainability benefits of this technology, knowledge and awareness campaigns would be an important first step to educating and training farmers on the merits of motor tuning and other operational measures to

116 As mentioned in Step 2, if the testing is performed until the 8th year, the diesel fuel savings compensate the investment. However, if the testing is conducted in the last year of the tractor's economic life, the farmer likely does not have adequate time to earn enough revenues to make up for his investment costs.

lower diesel consumption[117]. In particular, farmers could be informed when the appropriate time is to conduct motor tests to ensure maximum fuel savings.

The government could also increase the availability of services by equipping the country's technical visit centres, of which there are over 200, with additional equipment and training programs for the testing of agricultural machinery. This move could help to create a market for bench testing, which could further boost market penetration. To initially promote the services, the state could consider introducing subsidised testing sessions for a period of time and set a target for the number of tests to be conducted per year. Furthermore, the one-stop shops established to facilitate access to tractor subsidies could be expanded to incorporate facilities to coordinate motor testing and provide guidance to farmers on maintenance and management, among other activities. None of these tasks would likely require significant institutional or investment coordination, thereby increasing the viability of technological uptake.

Table 76: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• Set a target for the number of tests to be conducted per year	• N/R	• The state could initially support bench testing through subsidies (in particular for poorer farmers)	• Awareness campaigns • Equip technical visit centres with appropriate testing equipment	**

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

117 These other measures are included in Step 2, and would not require specific investments, but rather awareness on the part of farmers.

Drip irrigation

Diagnostics: policies and institutions

Table 77: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• Increase area under drip irrigation to 550 000 ha between 2010–2020 • By 2020, double value added per m^3 of water • No mention in the National Communication	• Upcoming law on groundwater • Revision of law 10–95	• Subsidies of 80% for individual investment projects, 100% for collective projects • Water pricing subsidies	• PNEEI expenditures

Source: Authors' compilation.

Morocco's water resources are governed at the national level by the Ministry of Energy, Mines, Water and the Environment[118], but there are many other institutions that intervene in water issues, such as the MAPM and the High Commission in charge of Water, Forests and the Fight against Desertification (*Haut-Commissariat Chargé des Eaux et des Forêts et de la Lutte Contre la Désertification*)[119]. The sector is governed by the water law 10-95, which was adopted in 1995 and is in the process of being updated. According to Abdesslam Zyiad of the Office of Research and Water Planning (*La direction de la Recherche et de la Planification de l'Eau*), the revisions are expected to clarify a number of concepts and improve text on issues such as the exploitation of rainwater and wastewater and protection against floods[120].

National irrigation policies are overseen by the MAPM[121], and have received considerable attention since the launch of the PMV in 2008. For example, the PMV aims to promote the conversion of areas dedicated to cereals into high value crop production, such as fruit farming – a move that will encourage the

118 The Ministry of Water is represented at the regional level by the Hydraulic Basins Agencies (*les Agences de Bassins Hydrauliques*), and at the provincial level by water services.

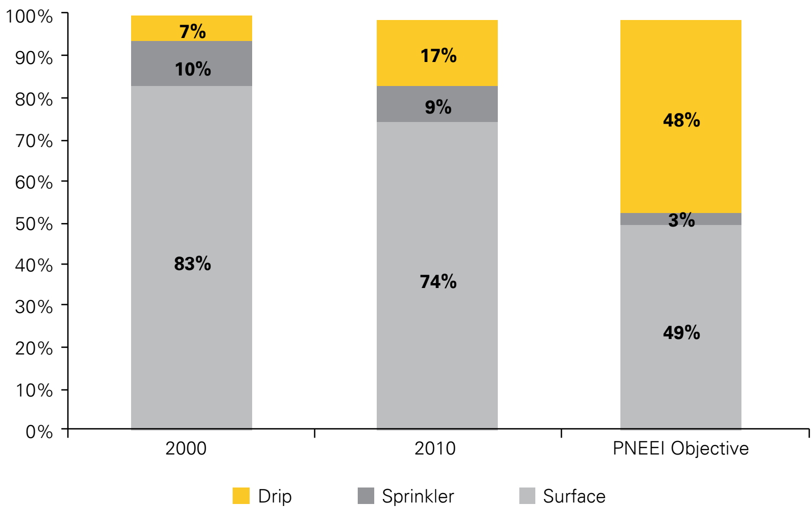
119 Other institutions include the National Environmental Council (*Conseil National de l'Environnement*, CNE), the Regional Environmental Councils (*Conseils Régionaux de l'Environnement*, CRE), etc.

120 One of the major cited drawbacks of the current legislation is that concepts are poorly defined, thereby leaving various ambiguities in the interpretation and implementation of the law. Quid, 2015. Abdesslam Zyid: *Diagnostic de la loi 10-95 sur l'eau entre acquis et contraintes*. http://www.quid.ma/economie/abdesslam-zyiad-diagnostic-loi-10-95-leau-acquis-contraintes/.

121 The policies of the MAPM are executed at the regional level by the Regional Agricultural Directives (*les Directions Régionales de l'Agriculture*) and at the provincial level by the Provincial Directives (*Directions Régionales de l'Agriculture*) and the Regional Offices of Agricultural Development (*les Directions Provinciales et les Offices Régionaux de Mise en Valeur Agricole*).

adoption of drip irrigation (IFC, 2014). The government has also implemented the *Programme National d'Economie d'Eau d'Irrigation* (PNEEI) under the PMV, which seeks to increase the current area under drip irrigation to about 550 000 hectares[122], or 49 percent of irrigated land (surface and/or sprinkler) between 2010 and 2020 (Figure 42), and to double the value added per m^3 of water by the end of the programme (FAO, 2015a). The PNEEI ultimately aims to convert surface and sprinkler irrigation to drip irrigation over an area of 920 000 ha, resulting in water savings of 2.4 billion m^3/year (Morocco INDC, 2015).

Figure 42: Irrigation systems and objective of the PNEEI, 2000 and 2010



Source: IFC, 2014.

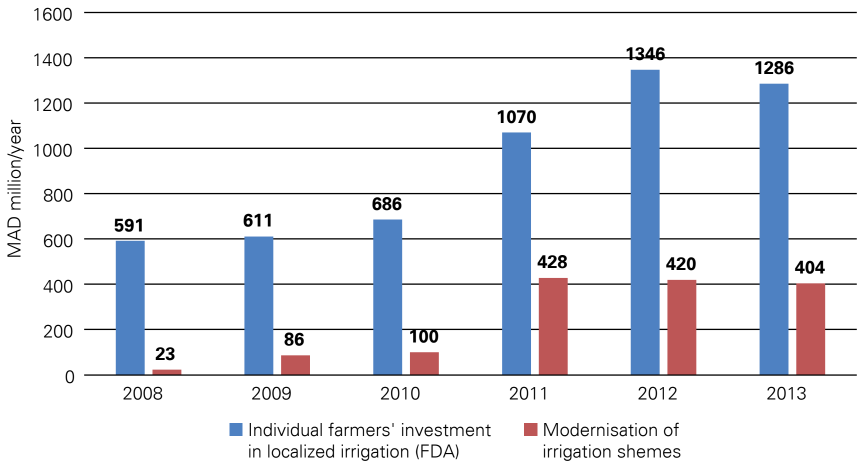
The project to modernise irrigation systems will mobilise nearly MAD 37 billion of investments to transform traditional irrigation systems into localised irrigation and to support farmers and managers to make profits from new equipment[123]. Figure 43 shows the evolution of investments by the PNEEI from 2008 to 2013, divided into two categories: equipment for drip irrigation farms and the modernization of collective irrigation systems (MAPM, 2014)[124].

122 Of this, 220 000 ha will come from collective reconversion and 330 000 ha from individual reconversion (IFC, 2014).

123 Through capacity building, adaptive research, etc.

124 Morocco has also a *Programme d'Extension de l'Irrigation* (expansion of irrigation program, PEI or IEP), which targets the irrigated area related to dams and covers nearly 159 280 ha associated with 14 dams. The dams are located mainly in the basins of Sebou and Loukkos in northern Morocco and cover 9 regions (FAO, 2015).

Figure 43: Evolution of investments by the PNEEI, 2008–2013



Source: MAPM, 2014.

The government aims to encourage the adoption of drip irrigation through a number of attractive subsidy programs. For example, farmers with plots over 5 ha will receive a subsidy of up to 80 percent of the investment for individual investment from the FDA, while farmers with plots under 5 ha or collective irrigation projects will receive a subsidy of 100 percent of the value of investment (FDA, 2015). An indirect financial incentive also exists, where farmers with drip irrigation may enjoy additional support to cultivate oranges or other small fruits, with conditions on the density of plants. The subsidy varies from USD 3.5 thousand to 11 thousand per hectare (MAPM/FDA, 2015d). Morocco also planned to introduce a subsidy programme for solar pumps paired with drip irrigation installations (IFC, 2015), though the programme was put on hold to investigate implications for groundwater exploitation. Currently, Morocco is preparing a new regulation on groundwater management, which may clarify appropriate boundaries for groundwater usage and ensure more sustainable usage of drip irrigation systems.

Another important factor affecting the penetration and adoption of drip irrigation relates to water pricing and use. In Morocco, tariffs for irrigation water use (VAT not included) vary accordingly (MAPM, 2014):

- from MAD 0.24 to 0.35 per m^3 for gravity systems without lift
- from MAD 0.36 to 0.47 per m^3 for gravity systems with lift
- from MAD 0.36 to 0.47 per m^3 for the pressure pipe networks for sprinkler irrigation

Barriers and risks

Table 78: Summary assessment of barriers and risks

Barriers						Risks
Knowledge and information	Organization/ social	Regulations/ Institutions	Support services/ structures	Financial returns	Access /cost of capital	
• Lack of farmer knowledge on how to use the technology	• Smaller farmers may need to join collectives, form groups to benefit from technology	• Lack of water governance • Administrative barriers to adopt technology • Lack of coordination between ministries and R&D institutions	• Few companies manufacturing technology parts thus far	• May not be attractive for certain crops • High maintenance costs • Returns may be diminished by need for other investments, e.g. wells	• Lack of access to credit • Upfront investment cost very high for smaller farmers	• Environmental benefits depend on previous irrigation system in place, local conditions; otherwise could increase energy requirements

Source: Authors' compilation.

A primary barrier to the adoption of drip irrigation relates to regulatory constraints, particularly in the limited governance of water. Specifically, as mentioned in Step 3, the conversion to drip irrigation may not necessarily lead to a decline in water usage, as similar amounts of water may continue to be abstracted following the shift from flood to drip irrigation. The introduction of drip irrigation may therefore need to be accompanied by restrictions on farmers' water usage to avoid water depletion. However, some of these issues will theoretically be addressed with the revision of Law 10-95 on water and the implementation of a new law governing groundwater usage. Other regulatory barriers include administrative challenges to adopt the technology and a lack of coordination between industries and R&D institutions.

Financial returns and the cost of capital constitute two other major barriers. Although financial returns are attractive in a number of scenarios due to generous state subsidies, drip irrigation may not appeal to the farmers of certain crops such as wheat[125], while maintenance costs and the need for additional investments in facilities such as wells may dampen enthusiasm for technological uptake. Despite the provision of subsidies, many farmers suffer from a lack of access to capital, therefore smallholders may still be unable to afford investment costs, which stand at USD 4 600 even with the 80 percent subsidy.

125 Berrada (2009) mentions that many farmers are not convinced whether drip irrigation would be profitable for crops such as wheat, barley and alfalfa. This is important, since in order to be financial attractive, drip irrigation might require a shift from the crops that are now dominant in surface irrigation systems according to FAO (2012c), implying an increase in water requirements.

In fact, Berrada (2009) reports that most areas equipped with drip irrigation in Morocco in 2008 belonged to medium- or large-scale owners, indicating that this type of technology may not be a feasible investment for the majority of smallholders. While this state of affairs provides an incentive for smallholders to aggregate their activities around collective irrigation projects, farmers may face organizational barriers related to the challenges of managing a group of farmers, which could inhibit the widespread adoption of drip irrigation.

Drip irrigation is a technology that is relatively easy to implement and can be adapted to the particular conditions of each context. However, a lack of adequate knowledge and experience can result in problems such as the incorrect application of nutrients through fertigation, the application of too much water and a lack of capacity to maintain and operate equipment, therefore farmer training to manage and monitor equipment is important. Despite these constraints, the general availability of technical skills for the operation and management of drip irrigation systems is relatively high, which will benefit the adoption of this technology. Additionally, a few companies have already begun to manufacture drip irrigation equipment in Morocco under license, expanding the reach of local support services. Though there is room for improvement with regards to production standards and technical instruction to farmers, as the use of drip irrigation increases, it is expected that a small auxiliary industry and market will develop centred on the commercialisation of new systems and on equipment replacement and maintenance.

Finally, as discussed in Step 2, drip irrigation must be deployed within the correct environmental context, as its usage in certain environments may increase energy requirements for water pumping. Specifically, the replacement of surface irrigation in locations where water previously supplied through gravity can risk increasing GHG emissions.

Key instruments/policies/drivers to overcome barriers

The Moroccan government has enjoyed a positive track record in promoting the uptake of drip irrigation: from 2002 to 2012, the share of surface under drip irrigation increased from 7 to 23 percent, according to the IFC (2015), mostly due to subsidies. A similar trend is confirmed by the data from the MAPM, which reports a sharp increase in the area of land equipped with drip irrigation during the same period, from about 100 000 to a bit less than 300 000 ha.

Despite the success of subsidies thus far, an accelerated rate of uptake could be promoted by complementing subsidies with new interventions in water use monitoring and pricing. Government training and support programmes could also be held to highlight the benefits of drip irrigation and educate farmers on proper use and maintenance. During these sessions, smallholder farmers could be unified to establish collective irrigation projects, enabling farms of all sizes to benefit from state subsidies. One of the larger institutional challenges to promoting drip irrigation relates to the revision of Law 10-95 on water and the design and implementation of the law governing groundwater. Morocco faces serious constraints related to water scarcity, and will need to find the appropriate balance between ensuring environmental sustainability and affordable access to water for farmers. This will require significant institutional cooperation due to the large number of ministries and institutions dealing with water management and governance. However, leaving aside the substantial reforms needed to address this barrier, the government should face relatively low institutional and investment costs to address remaining challenges to technological uptake, and therefore the policy reform intensity level is deemed moderate.

Table 79: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• Positive track record with drip irrigation uptake	• Implement a comprehensive groundwater law and revise Law 10-95	• Promote drip irrigation alongside interventions in water use monitoring and pricing	• Provide farmer training programmes that can also unify smallholders into organized units	**

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

Solar/wind-powered water pumping

Diagnostics: policies and institutions

Table 80: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• Install 30 000 solar pumping systems between 2015 and 2025, as outlined in the National Communication	• No major regulations have been able to make a large impact to date, though a law on water management is being discussed.	• Cover up to 50% of investment costs for all types of solar pumping systems under the National Programme for Solar Pumping in Irrigation Water Savings Projects • Grant under the National Programme for Solar Pumping, though it has not yet been implemented	• Under the National Programme for Solar Pumps, state investments are estimated at EUR 90 million for 2015–2025

Source: Authors' compilation.

Morocco has set ambitious goals for the RE sector, which will rely in part on the adoption of solar/wind-powered water pumping technologies[126]. Wind-powered, and to a lesser extent solar pumps, are not yet widely used and have relatively low market shares, due to the fact that LPG-powered pumps are currently cheaper. Although the IFC (2015) estimates that less than 10 percent of Morocco's 165 000 pumps are operated with solar energy, the potential for this technology remains interesting in light of the country's energy potential from the sun and government efforts to increase penetration[127]. Solar pumps in particular have received considerable strategic emphasis from the government as a method to reduce GHG emissions; through their deployment, the state aims to reduce 1 384 ktCO_2eq between 2015 and 2030 (MEM, 2016).

Support for RE-powered pumps comes from a number of ministries, notably the MAPM, the MEM, ADEREE, and CAM. To enhance the cost competitiveness of solar-powered pumps vis-à-vis LPG-powered pumps, improve agricultural productivity, and reduce unsustainable subsidies for fossil fuels, in 2013, these

126 Major targets and initiatives including a pledge to obtain 42 percent of electricity generation from renewables by 2020, and the construction of the world's largest solar plant at Ouarzazate, for which the first phase went online in February 2016.

127 The financial viability of solar and wind water pumping systems in the country is favoured by the fact that conventional fuels are expensive and conventional systems such as diesel pumps are difficult to maintain (Zein, 2014).

institutions supported the establishment of the National Programme for Solar Pumping in Irrigation Water Saving Projects. The programme initially envisioned the disbursement of MAD 400 million in state funds via the CAM, which would support technological adoption by covering up to 50 percent of investment costs[128]. However, the grant has not yet been implemented due to concerns over implications for groundwater exploitation (ANAFIDE & ADEREE, 2014), and a study was launched to explore this environmental risk[129]. The government is in the process of finalising a law on water governance, which is anticipated to facilitate water management at the central, regional and local levels[130]. As a result, many farmers have postponed their purchases of solar pumping systems in order to benefit from the subsidy once it is made available (Missaoui, 2014).

Despite these setbacks, the deployment of solar pumps remains a priority for the Moroccan government, exemplified by the announcement in the third National Communication document to expand the solar pump programme. The programme now aims to install 30 000 PV pumping systems between 2015 and 2025 and provide grants to farmers on small-sized farms for all types of solar pumping systems[131]. Funding covers 50 percent of investment costs and will be made available to projects with a ceiling of MAD 75 000, and total government investment is estimated to reach EUR 90 million for 2015–2025. Consequently, cost reductions in solar PV and wind technology, coupled with policy support, are therefore expected to support an increasing trend in the adoption of solar/wind-powered water pumping in Morocco (REN21, 2013).

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128 The programme is designed to facilitate access to credit for the remainder of investment costs. See Missaoui, 2014, p. 22 for more details.

129 For more information on the study, see: *Communications orales et discussions lors de l'atelier conjoint Banque Mondiale-ADEREE. Le pompage solaire en agriculture: expériences internationales*. 26 mai 2015. Rabat.

130 For more information on the water law, see: *Conseil Economique, Social et Environnemental*, 2014.

131 Small-scale Moroccan farms are considered farms with an area of 5 ha and under. Small-sized farmers were targeted in this project for a number of reasons, notably because such farmers are major consumers of butane, and because they are generally most disadvantaged in terms of access to credit. This programme is expected to be extended to include medium farms (up to 10 ha) as well (IFC, 2014). For more information, see Rafik Missaoui, 2014. Facilitating Implementation and Readiness for Mitigation (FIRM) Project – Morocco, NAMA for large-scale deployment of solar pumping in irrigation water savings projects. Ministry of Energy, Mining, Water and Environment and Directorate of Observation and Planning.

Barriers and risks

Table 81: Summary assessment of barriers and risks

Barriers						Risks
Knowledge and information	Organization/ social	Regulations/ Institutions	Support services/ structures	Financial returns	Access /cost of capital	
• Lack of farmer knowledge about the technology • Not enough technical expertise to use the technology adequately	• N/R	• Limited water governance • Limitations on ability to sell surplus electricity to the grid	• Limited R&D and coordination between industry and universities • Lack of product standardisation and quality assurance for technologies	• Not financially competitive vis-à-vis subsidised LPG pumps • Butane subsidies	• Lack of access to credit • Upfront investment cost very high • High investment costs without state subsidies	• RE-powered pumps may encourage overexploitation of groundwater resources

Source: Authors' compilation.

The primary obstacles to wider market penetration reside at the regulatory, financial and cost of capital level. Currently, private producers of RE can only sell up to 20 percent of their annual production to the grid. Additionally, although there are plans to open the low-voltage grid to renewable power installations, the details have not yet been determined, which may slow investments in this type of technology[132]. The preservation of subsidies to fossil fuels, particularly LPG, also represents a major regulatory and financial barrier, as the maintenance of butane subsidies erodes the cost competitiveness of RE pumps. Solar and wind-powered pumps have higher investment costs than conventional pumps, particularly for pumps with a battery [133]. The effect of high investment costs is compounded by the challenge of accessing capital for smallholders, which represents a broader problem in the Moroccan agricultural sector (IFC, 2015).

Consequently, as discussed in Step 2, in the absence of a subsidy to install solar pumps, the use of subsidised butane gas in powering water pumps creates little or no incentive to change to renewable pumps, though for larger systems, farmers may have increased incentive to convert [134]. However, if an

132 See Step 4 on renewable energy for more information.

133 According to Lorentz (2013), the initial capital cost of a PV pump (10 kWp) is USD 16 800, versus only USD 6 000 for LPG pumps, while investment costs for wind pumps (10 kWp) can add up to USD 15 000–17 000 (Zein, 2014).

134 Pumps using butane gas also offer other advantages, including lower installation and investment costs, and do not have the same availability constraints as power generated by wind or solar power (INRA-ICARDA, 2015).

installation subsidy is put in place and the subsidy to butane gas is scrapped, the returns for solar systems would be financially feasible[135]. Additionally, as the technology becomes more common and services more widespread throughout the country, farmers may benefit from declining installation and maintenance costs, thereby augmenting the potential financial returns.

Another barrier to the widespread adoption of solar and wind-powered pumps lies in the limited knowledge and information of these technologies. Although solar pumping systems have been utilised in Morocco since the 1980s, the majority of farmers have limited knowledge of PV pumping technology, due in part to a lack of awareness campaigns and information dissemination (Missaoui, 2014). Technological uptake is also slowed by gaps in human capital at the technical level. According to the MEM (2016), there is a shortage of adequate training programmes in schools and universities, a lack of projects in R&D and limited collaboration between the industry and universities. This contributes to an overall shortage of qualified individuals in this field, thereby reducing the quality of support services and structures to the sector. At the same time, the IFC (2015) has observed a lack of production standardisation and quality assurance for the technologies, which further limits the widespread deployment of solar irrigation systems (IFC, 2015). Finally, as seen in the implementation of the National Solar Pumping Programme, this technology may pose an environmental risk in the absence of comprehensive legislation to manage groundwater resources.

Key instruments/policies/drivers to overcome barriers

Although the Moroccan state has prioritised the deployment of RE technologies, the potential market penetration rate for solar and wind-powered pumps has not been fully realised. However, a number of initiatives could improve the track record of these technologies and aid the government in achieving its objectives. For example, the revision of butane subsidies would improve the cost competitiveness of solar-powered pumps and provide an incentive for farmers to switch technologies. The implementation of a comprehensive law on water governance could ease concerns over water exploitation, particularly if complemented by the installation of water metering systems that limit pumping to a certain level per day. An innovative power buy-back scheme could also promote water and energy efficiency, wherein the state buys back excess energy produced from solar irrigation pumps, offering farmers an

135 The results for wind-powered pumping are similar, but would require even more financial support from the government due to the higher investment costs of a wind pump irrigation system. Wind-powered systems, however, usually require more expensive storage capacity: 4 and 6 days' worth of water for wind versus only 2 days for PV, and investors in Morocco seem to have a preference for solar-powered systems.

incentive to conserve energy and water[136]. The resolution of this issue may in turn facilitate the disbursement of government grants for RE-powered pumps, encouraging farmers to take advantage of subsidised installation costs to switch technologies[137]. Finally, awareness campaigns and training programs could enhance farmer understanding of the benefits of RE pumps, while reinforcing human and organizational capital within the sector.

In light of the political momentum behind the achievement of Morocco's RE targets, the aforementioned policy initiatives would not likely face major implementation challenges. The government is already exploring proposals to enable farmers to resell RE back to the grid, and current proposals could be expanded to include water efficiency considerations[138]. However, the reform of butane subsidies is a socially sensitive topic that may require considerable institutional effort to implement, despite the financial advantages to the government in terms of savings. The formulation of a national water law also requires considerable coordination between a multitude of ministries and industries, which may slow the implementation process. Thus, the policy reform intensity to support the adoption of solar/wind-powered pumps is considered high.

136 In the Indian state of Karnataka, the Surya Raitha Scheme provides farmers with renewable energy in the form of solar irrigation pumps, which, coupled with drip irrigation, can reduce water consumption. The power buy-back scheme then encourages farmers to pump only when they need to irrigate, while extra energy produced is bought back by the government. For more information, see Siddiqi, 2015. "Growing more with less – can innovations make a difference?" Asian Development Blog. Accessed at: http://blogs.adb.org/blog/growing-more-less-can-innovations-make-difference.

137 Investment costs could be further reduced with the introduction of dedicated credit lines and a loan guarantee facility for renewable energy producers (IFC, 2015).

138 For example, Law No. 13-09 is working to pave the way for renewable energy producers to sell their excess energy to consumers. However, producers have expressed concerns at the slow implementation of other related laws. For more information, see MEM, 2010.

Table 82: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• Aforementioned state targets for RE pump installations, broader RE goals for sector	• Removal/ reduction in butane subsidies • Implementation of a water governance law	• Disbursing RE pump investment grants • Introduce a system wherein farmers can sell back unused renewable energy to the grid	• Campaigns to spread awareness • Facilitate access to credit for RE users • Capacity development of public and private players, extension support services	*

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

Grazing management

Diagnostics: policies and institutions

Table 83: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• 4.2 million ha recovered in the next 10 years (PANLCD) • Brief mention in the National Communication, though the role in mitigation is not explored	• N/R	• Government provides subsidies on physical assets, compensations and technical assistance	• Projects have been piloted in the 2000s in coordination with IFAD

Source: Authors' compilation.

Policies surrounding grazing management are addressed by a number of different ministries, including the MAPM, the Interior Ministry, and the *Haut-Commissariat aux Eaux, Forêts et à la Lutte contre la Désertification*. The MAPM oversees a programme to manage and improve grazing lands through various means, such as the planting of fodder shrubs, the introduction of techniques to collect rainwater, and support for income generating activities amongst herders. Certain projects have also led to the development of smaller management mechanisms, such as regional, provincial and local commissions that are comprised of local authorities, external technical services and beneficiaries. The Moroccan government has invested in grazing management initiatives in coordination with international organizations, namely IFAD, which launched projects to improve grazing practices and establish herder cooperatives, as mentioned in Step 2. Finally, grazing management was a major theme within the "Prospective 'Maroc 2030'" document, which emphasised the importance of herder livelihoods and improved grazing practices within broader efforts to combat desertification and land degradation[139] – a theme that was also discussed briefly in the 3rd National Communication. However, the theme was not examined in either document as a source to reduce GHG emissions.

Currently, there are no targets or regulations for reducing GHG emissions within the context of grazing management, but there is a recovery target of 4.2 million ha of rangeland for the next 10 years in the PANLCD; a project under implementation in *Sous Massa Drâa* and *Guelmin Es-Semara* targeting 400 000 ha; and a project under formulation targeting 45 000 ha in *Drâa-Tafilalet*. Such programmes provide generous subsidies towards initial investments for grazeland management improvement, as well as technical assistance to improve grazing management, herder organization into cooperatives and value addition to local production.

139 HCP, 2006: p.17, 40.

Barriers and risks

Table 84: Summary assessment of barriers and risks

Barriers						Risks
Knowledge and information	Organization/ social	Regulations/ Institutions	Support services/ structures	Financial returns	Access /cost of capital	
• Limited knowledge and experience amongst herders and technicians on best practices to reduce GHG emissions	• Need for considerable coordination to form herder cooperatives • Must consider characteristics of local population in project design and implementation • The management of pastoral lands can generate conflicts between herders • Demographic pressures and the disappearance of pastoral cultures constrain expansion and create competition amongst herders	• Coordination between different ministries is difficult • Lack of clarity on land status of collective grazing lands and administrative boundaries	• Limited experience in providing support	• Not financially attractive to herders without state subsidies	• Lack of access to credit • Upfront investment cost very high	• Increases energy consumption • Environmental factors, such as drought may condition the success of practices

Source: Authors' compilation.

Some major challenges facing the penetration of improved grazing management practices include financial returns, cost of capital and the organization of herders**.** The financial analysis conducted in Step 2 indicates that subsidies (in investments in physical assets, technical assistance and compensation) play a major role in rendering improved grazing management practices financially attractive to farmers and herders. According to the calculations in Step 2, without government subsidies, the financial returns would not be attractive for herders due to high capital costs and delayed revenues. The low appeal of limited financial returns is compounded by a general lack of access to credit. These barriers are therefore likely a primary reason why the adoption of improved and sustainable grazing management practices has been slow in Morocco.

Previous projects have also cited a number of regulatory and institutional constraints that have dampened outcomes. In the IFAD projects cited in Step 2, the delegation of different tasks between various institutions led to coordination and management challenges (IFAD, 2016). The projects also reported barriers from the lack of clarity on the land status of collective grazing lands, and administrative boundaries, which are not always recognised between rural communities. The implementation of grazing management projects also requires a high level of organization amongst a large number of stakeholders, particularly when creating herder cooperatives, as well as an analysis of unique social conditions. For example, the management of pastoral lands can generate conflict between herders. The IFAD projects cited the importance of considering the organization and structure of local populations in grazing management projects, which is necessary to fully integrate beneficiaries into projects with local authorities and technical staff. More broadly, demographic pressures and societal changes both constrain land availability for this practice and contribute to the disappearance of pastoral cultures, while creating competition amongst herders.

As previously mentioned, few projects to improve grazing management exist in Morocco; and although there are best practices being implemented in the country, practices to reduce GHG emissions have not been implemented on a large scale. Consequently, the existing knowledge and experience of technicians and herders of such practices is limited. Similarly, support services have little experience in providing assistance. Based on the analysis from Step 3, improving grazing management practices would generally have a positive sustainability impact in a number of ways. However, this practice does run the risk of increasing energy needs[140]. More broadly, successful implementation may be adversely impacted by climatic conditions. For example, the performance of an IFAD project suffered due to a deficit in rainfall, which led to a general degradation of grazing lands.

140 Increased energy needs stem from the manufacturing, installation and operation of necessary infrastructure for grazing stock and the restoration of degraded lands.

Key instruments/policies/drivers to overcome barriers

Table 85: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• Advocate targets already set for implementing improved grazing practices in applicable environments	• Better define land status on collective grazing lands, and clarify administrative boundaries	• Maintain/ expand subsidies for initial investments and technical assistance	• Pilot programmes with lead/ larger farmers for demonstration • Capacity development of public and private extension support services • Reinforce cooperatives	**

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

Due to the dearth of projects implemented, there is a limited track record to inform the design of new projects. However, based on the experiences of IFAD-funded projects, it is important to better define the land status on collective grazing lands, as well as administrative boundaries. Government promotion of cooperatives and the development of pilot programmes and extension support services would be essential steps to increasing adoption. The maintenance of government subsidies for initial investments, coordination and technical assistance for best practices, building a track record and communicating on progress on target achievement is also integral to ensuring the financial feasibility of these projects through the medium term. Additional targets could be set to increase the production of value added livestock products, which could incentivise continuous and sustained improved graze land management. Given the resources and efforts required to carry out the aforementioned tasks, adoption of best grazing practices implies a relatively high level of investment and public sector involvement. Attention also needs to be paid during interventions to resolve legal, regulatory, institutional and organizational coordination issues to expand the adoption of improved grazing management practices. However, programmes already exist that consider all these elements and there is no need for heavy changes in the existing regulatory framework. Consequently, we consider the policy reform intensity to be medium for this technology.

Manure as soil amendment

Diagnostics: policies and institutions

Table 86: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• No specific national targets	• Law 28-00 from 2006 manages agricultural waste disposal and treatment • Law 49-99 from 2004 regulates the conditions for disposal of poultry manure • Regarding compost, there is not an official normative document and only suggested norms by researchers	• Currently a 30% subsidy on equipment to apply organic material on farm (up to MAD 48 000 per unit)	• Some indirect support through research programmes and studies

Source: Authors' compilation.

The key institution dealing with waste management plans in Morocco is MEM, which provides strategic guidance on waste management and value addition. In addition, given the specificities of the agricultural sector, the MAPM also plays an important role (including its Livestock Directorate), in particular in executing key decrees on treatment of manure (for example decrees relating to law 49-99 on the poultry sector).

As part of its INDC[141], Morocco has laid out clear targets for waste management, namely through a broad set of initiatives such as the establishment of landfill and recycling centres for household waste and improving its collection, as well as raising awareness levels and ensuring compliance. Among others, the country aims to achieve 100 percent wastewater treatment and a 100 percent household waste urban collection rate by 2030. While many strategic documents discuss agrifood sector waste (both from primary agriculture but also from agro-processing activities), there are no clear targets regarding reuse or management of manure or related waste streams.

So-called "green" waste and agricultural waste are regulated by the law 28-00 from December 2006. The law stipulated that in 5 years (from 2011) every region in Morocco would need to have a master plan for management of waste, including specific targets for the collection and elimination of agriculture and

141 Morocco INDC under the UNFCCC was officially presented in 2015.

other waste. Regarding agricultural waste, the law (article 24) established that the agents creating the waste should be responsible for their collection and disposal in appropriate installations. However, it also allowed an exception for "biodegradable agricultural waste", which can be used or eliminated in the agricultural land that produce them (article 28). The law also included fines of up to MAD 10 000 for individuals disposing of agricultural waste inappropriately. On compost, there are only technical norms suggested by researchers but reportedly Morocco still does not have a regulatory environment establishing rules on composting.

Regarding price incentives, the FDA included a 40 percent subsidy in 2013 on equipment for transportation and application of organic matters for tractors (one per tractor) up to MAD 64 000 per unit. In 2015 the subsidy was reduced to 30 percent with a MAD 48 000 ceiling per unit. Regarding value addition to agriculture waste, there are overall no major support measures.

As with other technologies, the government has funded research activities linked to composting and impact of manure management. However, there are no major public programmes and expenditures aimed at promoting such practices.

Barriers and risks

Table 87: Summary assessment of barriers and risks

Barriers						Risks
Knowledge and information	Organization/ social	Regulations/ Institutions	Support services/ structures	Financial returns	Access/ cost of capital	
• Low levels of awareness at the farmer level on the problems and risks with directly applying manure on soil • There is generally inefficient fertilisation of soils in Morocco and a lack of knowledge on the need for organic matter • Currently there are operators already able to use modern composting technologies in the country	• Organization and social practices linked to livestock production increase the costs of efficient manure management • There is a lack of a critical mass in compost production	• While there are laws on waste management, not all decrees seem to be in place for the enforcement of such laws, and in particular, in terms of agricultural waste • Composting norms and regulations are still not available	• There is no major need for support services	• Manure management comes at a cost to farmers and is not financially attractive unless there are higher penalties from non-adoption • Compost seems to be potentially profitable	• Upfront investment cost is not high	• No major risks

Source: Authors' compilation.

The technical and economic analysis in Step 2 suggests that the main barriers to adoption of efficient manure management techniques in Morocco are primarily the financial returns, and related to that, the regulatory environment. In fact, efficient manure management is mainly a cost to the farmer as long as no compensation is offered for the positive externalities related to climate change mitigation through public intervention. The regulatory environment could play an important role by providing clear norms on soil fertilization and also on composting products.

To some extent, knowledge and information about soil fertility and problems related to direct application of manure (including weed problems and pathogens) also constraint growth in the market for compost relative to fresh manure applications. The sustainability risks related to efficient manure management are not relevant as evidenced by the analysis in Step 3.

Key instruments/policies/drivers to overcome barriers

Following the analysis above, this section summarises relevant policy themes that could be interesting to develop. The analysis suggests that a national target for efficient manure utilisation could be formed (in combination with biogas and other considerations). This would, however, most likely require further studies and analysis on potential for different manure applications including efficient manure management, composting and biogas (the latter is treated in a separate note). In terms of regulations, a more enabling environment for manure management could be created. As discussed above, the critical issue from a public policy perspective is that manure management comes at a net cost that can be allocated to the farmer, for example through extra regulation and enforcement, or to taxpayers and consumers by following an Irish *Origin Green*[142] type of approach of creating financial incentives coupled with market mechanisms for farmers to adopt such techniques. Incentives would probably take the form of price incentives on efficient manure management but would be difficult to adopt, given fiscal constraints and the range of priorities for rural development in Morocco. It is also unlikely that a sufficient number of Moroccan consumers would pay a price premium for sustainably produced milk or meat. Awareness raising both at farm level and with consumers (as in the Irish case) would be expected to have only limited impact at present in the Moroccan context. Finally the public spending on studies and analysis on bio-fertiliser alternatives and creating an enabling environment for efficient use of manure would be warranted. Given the difficulties facing this set of technologies, the policy reform intensity to promote greater adoption is considered high.

142 Origin Green is an independently verified certification and support programme which enables Ireland's farmers and producers to set and achieve measurable sustainability targets, reducing the environmental impact of their production - http://www.origingreen.ie.

Table 88: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• Targets on efficient management of agricultural waste products can provide a signal along with existing targets for household waste and others	• Certification and clear norms on compost can support market development • Regulations on manure management could support technology adoption but would translate into costs	• Manure management would require incentives to internalise externalities	• Increased spending on enforcement of correct disposal of agricultural waste • Studies and data collection focusing on soil fertility management and bio-fertiliser alternatives	*

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects the complexity of expected policy changes, institutional/administrative implications and/or budgetary implications: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

Livestock dairy breeds on improved diets

Diagnostics: policies and institutions

Table 89: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• Targets from FIMALAIT, though there are not targets directly related to emissions reduction	• There are no regulations that have an impact	• Various indirect subsidies are in place that could lower investment costs in improved livestock breeds and diets	• PICCPMV project invests in improving livestock adaptation to climate change • Indirect support through ONSSA

Source: Authors' compilation.

The development of the livestock sector is overseen by the Office for the Development of Production Chains (*Direction de Développement des Filières de Production*) within the MAPM, while institutions like the National Office for the Health Safety of Food Products (*L'Office National de Sécurité Sanitaire des Produits Alimentaires* [ONSSA]) and the ONCA[143] address issues related to food

143 ONCA.

safety and agricultural advice. The livestock sector is also a priority within the PICCPMV, which has implemented a project to promote CCA in the industry. The project aims to improve the productivity of livestock production through the development of genetic breeds and techniques for food, reproduction and hygiene. However, unlike the scenario envisioned in Step 2, the PICCPMV project does not consider the adoption of purebreds for emissions reduction, but rather promotes the adoption of local and crossbred cattle for CCA[144].

The industry is organized by the Inter-professional Moroccan Federation of Milk (*Fédération Interprofessionnelle Marocaine du Lait* [FIMALAIT]), which encompasses both producers and processors. FIMALAIT has set ambitious targets for sector development, such as an increase in production to 4.5 billion litres of milk by 2020, and an improvement in the quality of milk produced at all levels of the value chain. It anticipates an investment of USD 1.2 billion to achieve these objectives, which will create around 40 000 direct permanent jobs (FIMALAIT, 2013).

Although there are currently no direct subsidies in place to support the adoption of improved livestock breeds and diets, there are other measures that may reduce costs for farmers investing in this climate-smart technology. For example, there is a 30 percent subsidy in place for various pieces of animal husbandry equipment and a subsidy of up to 25 percent for the cost of cowsheds up to USD 20/m^2. Additionally, a subsidy of MAD 2 000 per head is in place for the rearing of crossbred calves until 8 months of age (industrial crossbreeding).

144 For more information, see Balaghi et al., 2011.

Barriers and risks

Table 90: Summary assessment of barriers and risks

Barriers						Risks
Knowledge and information	Organization/ social	Regulations/ Institutions	Support services/ structures	Financial returns	Access /cost of capital	
• There is a lack of farmer knowledge about the technology • There is a lack of widespread technical expertise to use the technology adequately	• Small farmers may need additional organizational and social support to be able to afford purebreds	• There is limited institutional and regulatory support for the uptake of this technology • No relevant targets exist to encourage uptake	• Limited resources are available for maintaining improved breeds	• Attractive returns • Requires higher operational costs that smaller farmers may not be able to afford	• Lack of access to credit for smallholders in particular • Upfront investment cost of improved breeds high	• Water sustainability risks

Source: Authors' compilation.

Technological uptake is slowed in large part by limited institutional and regulatory support; although state institutions have begun developing policies and programmes to improve livestock resilience to climate change, the sector's potential in climate change mitigation has not translated into relevant targets or policy initiatives. Additionally, the targets introduced by FIMALAIT do not directly promote the use of improved breeds, and therefore may not significantly contribute to increased technological uptake.

Access to capital poses another major challenge to technological adoption. The adoption of this technology requires higher initial investment costs than other livestock breeds and higher operational costs in terms of on-farm produced forage, concentrate and veterinary expenses, therefore the majority of farmers (who are smallholders), have limited financial flexibility to make these investments. Consequently, there may be a need for additional organizational/ social coordination between smallholders to pool resources and purchase more climate-smart breeds. For medium- to large-sized farmers who can afford the investment costs, however, the model simulated in Step 2 indicated financial returns that included IRRs between 20 and 37 percent depending on the farm model in switching breeds and improving diets. In particular, the income obtained from milk has the potential to rise on average from USD 546/cow/year to USD 888/cow/year, while calf sales for purebreds are also higher. However, as discussed in Step 2, these results depend on the changes in farming structure that may be required when switching to purebred herds or improved diets (housing, labour and equipment cost differences) and are very sensitive to changes in milk yields. The impact in each case is bound to differ from one to the other.

Using improved breeds and feed is a widely known technology by relevant technical institutions in the country and is practiced by a number of milk producers. However, larger market penetration would require the dissemination of special skills and knowledge that is still lacking in Morocco, especially among farmers, as well as some technicians and extension workers. In particular, there could be more education surrounding the benefits of improved breed cattle for reducing emissions and improving milk yields. Additionally, support services could be further developed to cater to the needs of farmers importing and maintaining purebreds. Finally, the sustainability risks related to livestock breeds and improvements, namely those related to scarce irrigation water use for increased forage production, need to be carefully assessed as evidenced by the analysis in Step 3. Although this technology can have a substantial impact on both reducing emissions and improving water and other resource efficiency, in absolute terms it may have a larger environmental impact than increasing milk supply through imports. Should national supply remain constant, then increases in milk productivity will have an absolute positive impact in water and land resources. This latter scenario would mean considerably reducing the number of cows (and farmers) in the country as the national herd becomes more efficient, which might prove difficult to achieve given FIMALAIT growth prospects.

Key instruments/policies/drivers to overcome barriers

Table 91: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• Setting specific targets for adoption of purebreds, improved diets could help this technology gain traction	• N/R	• N/R	• Pilot programmes with groups of farmers to illustrate benefits • Capacity development of extension services and farmers	**

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects the complexity of expected policy changes, institutional/administrative implications and/or budgetary implications: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

Taking the above analysis into consideration, there remains considerable scope for the promotion of this technology at the policy and institutional level. For example, the state could set specific targets to adopt climate-smart livestock breeds and improved diets. These initiatives would not require significant reform or investment costs. The state could also provide technical assistance to farmers and develop support extension services, while demonstrating the benefits of this technology by adding additional pilot programmes for purebreds within the framework of the PICCPMV. The provision of technical support would be useful for promoting changes in feeding practices and assessments of milk yield improvements in particular. Given the level of reform and budget allocations required (mainly in terms of supporting capacity development and pilot programmes and in developing targets), the policy reform intensity of supporting improved livestock breeds and diets in Morocco is deemed moderate.

Efficient water boilers

Diagnostics: policies and institutions

Table 92: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• There are no state targets for technological uptake • There is no mention in the National Communication (as of January 2016)	• There is a regulation on boilers regarding registration and inspection standards • However, there are no policies that can be thought to have a major impact on technological adoption	• There are no direct price incentives to encourage energy-efficiency improvements • The removal of fuel oil subsidy may indirectly impact adoption	• There are no noteworthy public initiatives promoting this technology

Source: Authors' compilation.

The MICEN oversees the steam industry, while the Department of Mines manages a regulation on boilers. Set in 1953, the regulation stipulates that boilers are subject to rules requiring the registration and inspection by the Department of Mines during their initial instalment or periods of important repairs[145].

The Moroccan government has not set any targets to promote energy efficiency in boilers, nor has it introduced any price incentives or public spending programs to encourage better boiler performance. Based on the absence of government initiatives, it does not appear that the refurbishment of boilers has been

145 The law was introduced on the 22 July 1953 (9 kaada 1372). For more information, see: Ministry of Energy and Mines, http://www.bci-inspection.com/pdfdoc/reglementation%20vapeur.pdf.

conceived as a potential source of GHG emission reductions by the state. It is therefore presumed that there is considerable scope for expanding the adoption of energy efficiency improvements in small- and medium-sized boilers. These changes may receive growing interest from consumers due to the fact that the state subsidy for fuel oil, which powers smaller boilers, was recently removed by the government. As consumers assume the full costs of fuel oil usage, they may seek energy efficiency measures that could reduce their consumption.

Barriers and risks

Table 93: Summary assessment of barriers and risks

Barriers						Risks
Knowledge and information	Organization/ social	Regulations/ Institutions	Support services/ structures	Financial returns	Access /cost of capital	
• There is a lack of knowledge about the technology • There is a need for more technical knowledge on energy efficiency maintenance measures • There is a lack of specialists in the steam industry	• N/R	• Regulatory gaps translate into little support for the standardisation and maintenance of boilers • There is no institutional emphasis on improving boiler energy efficiency	• Technical support is available and new boilers are generally efficient • However, there is a need for more emphasis on maintenance	• Attractive IRR under scenario assumed in Step 2 • There are no state subsidies to support maintenance • Competition from second-hand boilers	• Lack of access to credit • Upfront investment cost very high	• None – this technology would reduce the amount of fuel used in the sector, reducing energy needs and therefore GHG emissions

Source: Authors' compilation.

The regulatory and institutional setting likely poses the largest barrier to technological adoption in Morocco. Currently, there is no comprehensive legislation to standardise the boiler industry and ensure a minimum level of maintenance for boilers, despite supervision from the Department of Mines during periods of major repairs. Moreover, there is no institutional emphasis in the way of targets, policies or programmes to encourage boiler energy efficiency, likely slowing adoption. The absence of government support for technological uptake, coupled with limited access to credit and relatively high investment costs, also renders improvements in boiler performance difficult to afford for a significant part of the Moroccan agricultural sector. Additionally, this technology faces competition from imported second-hand boilers, which are cheap yet very inefficient and therefore contribute to higher GHG emissions.

Under the scenarios proposed in Step 2, individuals that can afford the upfront investment cost could enjoy an attractive IRR and a limited payback time as long as the boiler is used throughout the year.

Although the level of support services is high and new boilers are generally quite energy efficient, there is a need for an increased focus on maintenance measures to improve energy efficiency for all models. This gap stems in part from a lack of knowledge about the long-term benefits of this technology on the part of consumers, especially small-scale food processors, as well as limitations in technical knowledge and specialists in energy efficiency maintenance and the steam industry. As seen in Step 3, there are no sizeable sustainability risks, and this technology would produce benefits such as reduced fuel oil consumption and therefore lower GHG emissions for the sector.

Key instruments/policies/drivers to overcome barriers

Table 94: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• Setting targets for minimum maintenance standards could aid uptake	• Introduce a policy and regulatory framework to support the standardisation of boilers	• Support upfront investment costs • Removing fuel oil subsidies will likely help support technology adoption	• Support implementation of energy efficient boiler adoption projects and manufacturing • Capacity development of public and private extension support services	**

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects the complexity of expected policy changes, institutional/administrative implications and/or budgetary implications: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

Because this technology has received little attention to promote energy efficiency, it is difficult to assess the track record of technology adoption. The only prominent policy change in recent years that may affect technology uptake is the elimination of the fuel oil subsidy. However, since the subsidy was only removed recently, it is challenging to determine its impact on consumption. Nevertheless, it is likely that consumers will seek ways to reduce fuel oil consumption, and will thus consider investing in maintenance measures to improve energy efficiency in the coming years, as long as their boilers are not significantly underused.

Technological uptake would benefit from the establishment of a policy and regulatory framework to encourage the standardisation of boilers and introduce minimum standards in the industry. The Moroccan government could request support in formulating a framework from the local UNIDO office, as the latter institution has established a similar system in Vietnam[146]. This move could be complemented by the setting of targets to achieve a minimum level of boiler maintenance in the coming years. Public support to cover some of the initial investment costs may also facilitate access to this technology for smaller processors. More broadly, the development of awareness, training and capacity building initiatives for government agencies as well as boiler owners, operators, and manufacturers would likely encourage increased adoption. Taking these factors into account, Morocco's policy reform intensity is deemed moderate for promoting the uptake of energy-efficient boilers. Within this, the formulation of a national policy and regulatory framework would likely be moderately intensive, while investment costs would be relatively limited.

Efficient cold storage

Diagnostics: policies and institutions

Table 95: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• Eliminate HCFCs within 15 years • Despite being a priority, no specific targets have been set under the PMV or other policy documents • There is no mention in the National Communication (as of January 2016)	• N/R	• PDA finances 10% of installation of cold storages for agricultural products • There are no subsidies for retrofitting of cold storage facilities • Butane subsidies	• State grants are available for innovative projects

Source: Authors' compilation.

As previously mentioned, the demand for cold storage, especially for fruits and vegetables, is expected to increase sharply to meet the targets of the PMV. Although the volume of new and efficient storage facilities is increasing in Morocco, the amount of cold storage suitable for efficiency improvements will expand in real terms as more plants require refurbishment in the future. To help organize the cold chain sector, the MAPM has launched several

146 For more information on UNIDO's work in Vietnam to promote energy efficient industrial boiler adaptation and operating practices, see: UNIDO, 2015b.

initiatives, particularly improvements in energy efficiency. For example, the state has awarded subsidies to projects promoting enhanced efficiency in refrigeration services, while encouraging smallholder farmers to coordinate with cooperatives or larger growers to benefit from more efficient technologies (Ait-Oubahou et al., 2011). Since 1989, the CAM has also provided financial aid through subsidies and incentives to import equipment to construct new storage facilities. Additionally, the MAPM and the FDA subsidise up to 10 percent of the purchase price for cold storage facilities for agricultural products with a ceiling of MAD 2 224 000 per unit[147]. As discussed in Step 2, given that there is a strong demand for cold storage in Morocco, it is possible that with existing incentives, investing in new cold storage facilities may yield more interesting NPVs instead of retrofitting old ones. If that is the case, investment in new facilities will be given priority by investors.

Cold chains serving agricultural products will also be targeted by the Ministry of Equipment, Transportation and Logistics (*Ministère de l'Equipement, du Transport et de la Logistique*) through the PMV (*Ministère de l'Equipement et des Transports*, 2010). Specifically, the Ministry aims to develop logistics services relating to cold chains near or in the newly established *agropoles*, and encourage investments in cold chain infrastructure and equipment, including cold stores, refrigerated transport, as well as the maintenance and monitoring of cooling systems[148]. UNIDO also supported the Ministry of Industry, Trade, Investment and the Digital Economy (*Ministère de l'Industrie, du Commerce, de l'Investissement et de l'Economie Numérique*) to eliminate chlorofluorocarbons (CFCs) in accordance with the Montreal Protocol, and is devising a national plan to eliminate hydrochlorofluorocarbons (HCFCs) within 15 years (Hamdi, 2015). Furthermore, UNIDO is providing technical assistance to Moroccan industries to introduce environmentally sustainable technologies in the domain of industrial refrigeration and foam insulation in refrigeration systems. Finally, the control of refrigerated centres is maintained by the ONSSA.

Although the government seeks to promote energy efficient cold storage facilities, the preservation of butane subsidies may adversely impact the adoption of energy saving technologies. Specifically, some cold storage facilities are able to use subsidised gas or contract individual electricity prices for power, which may slow uptake, as discussed below.

147 The subsidy relates to construction and equipment costs of the units (FDA, 2013).

148 The MAPM envisions the establishment of six agropoles in the regions of Meknès, Berkane, Souss Massa, Tadla, Gharb et Haouz. For more information, see: ADA, 2013.

Barriers and risks

Table 96: Summary assessment of barriers and risks

Barriers						Risks
Knowledge and information	Organization/ social	Regulations/ Institutions	Support services/ structures	Financial returns	Access /cost of capital	
• There is a lack of knowledge about the technology and the benefits of energy efficiency improvements		• There is a need for industry standards that promote energy efficiency	• Repair shops exist for conventional equipment but may need to bolster support services experienced in energy efficiency measures	• Financial returns vary considerably depending on type of energy efficiency intervention • Without state subsidies, there may not be an incentive to introduce efficiency measures • Butane subsidies may dampen interest in energy-saving measures	• Lack of access to credit • Some interventions require significant upfront investments (ex*: Frigos de Marrakech*)	• N/R

Source: Authors' compilation.

Barriers in the regulatory, financial and cost of capital pose the largest threats to technological adoption. First, there are no industry standards or regulations in the cold storage chain to promote the adoption of energy efficiency measures. On the financial front, the returns associated with energy efficiency investments in cold storage are highly variant. Potential returns are therefore dependent on investment costs; in the case of *Frigos de Marrakech*, the substitution of the cork insulation had an estimated payback time of around 20 years, incurring negative financial returns. As a result, this type of climate-smart technology is not readily accessible for small entrepreneurs, who already have limited access to credit. Additionally, due to the variety of potential energy efficiency interventions available, cold storage owners must conduct preliminary energy audits to assess current energy performance and potential for efficiency gains of the concerned facilities, necessitating the presence of support services with experience in assessing and implementing energy-saving measures.

The issue of butane subsidies represents both a regulatory and financial constraint on the uptake of cold storage. If cold storage facilities are able to use subsidised butane gas, the financial attractiveness of investments in energy efficiency gains would decrease, and likely lead sector participants to postpone technological upgrades or purchases of new facilities.

Additionally, important knowledge gaps persist with regards to the benefits of cold storage facilities. Producers and traders are often not well-informed of the extent of postharvest losses generated by not using cold storage and the economic losses that result. Ait-Oubahou et al. (2012) also cited insufficient know-how, misuse of existing facilities and inappropriate storage conditions as barriers[149]. Finally, many sector participants are not aware of the available technical solutions to improve energy efficiency and insulation.

Key instruments/policies/drivers to overcome barriers

To overcome the aforementioned challenges, the Moroccan government could introduce targets for the adoption of efficient cold storage equipment, emphasising the uptake of VFD drives, LED lighting and sealed fast rollup or sliding doors in particular. These initiatives could be complemented by government-sponsored capacity development programmes for public and private support services, particularly in the implementation of energy audits and the installation and maintenance of energy efficient systems[150]. The reform of butane subsidies would require the most institutional coordination; in their absence, state subsidies to implement energy efficiency measures may be needed to incentivise change. In contrast, entrepreneur and support service training programmes would require relatively limited investment and institutional coordination, particularly if the state is able to draw on support from UNIDO. Consequently, the policy intensity of supporting cold storage is considered moderate.

149 Inappropriate storage conditions include issues with temperature, air circulation, humidity and air change.

150 Morocco already has over 140 private firms that are engaged in the import, conception, installation, support and maintenance of cold chains, therefore the government has a strong foundation upon which to improve support services.

Table 97: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• Introduce targets for the adoption of efficient cold storage equipment or energy efficiency targets	• N/R	• Revision of butane subsidies • Potentially expand state subsidies for improvements	• Entrepreneur awareness campaigns and training • Capacity development of support services	**

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects the complexity of expected policy changes, institutional/administrative implications and/or budgetary implications: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

Biogas from manure and agri-residues

Diagnostics: policies and institutions

Table 98: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• There are no targets set • The technology is briefly mentioned in the national communication, but it is not considered viable for electricity production	• Regulations exist but do not incentivise biogas production	• There are no incentives to encourage uptake	• Pilot projects have been conducted in recent years

Source: Authors' compilation.

A number of government ministries are involved in biogas-related issues, including the MEM, the Ministry of Interior, and the MAPM. Biogas production is seen as a mechanism to contribute to two national objectives: the production of renewable energies, through law 13-09 and law 58-15[151], and the management and recovery of waste, through law 28-00. To promote these goals, a number of projects were launched in coordination with international

151 Law 58-15 modified and complemented the renewable energy law 13-09 by introducing a net metering scheme for solar and wind-powered plants connected to the high-voltage grid. Upcoming legislation is expected to clarify requirements for producers connecting to the middle- and low-voltage grid.

partners, MAPM and ADEREE; however, the majority of these projects are household or small biogas installations. These installations were without commercial purpose and did not obtain positive outcomes in the long run.

Biogas is mentioned on several occasions in the 3rd National Communication document due to its importance within the government's broader strategy on waste management. However, although the state is exploring the technology's potential through pilot projects, there are currently no concrete targets for energy production from biogas. Additionally, there are no preferential tariffs for electricity generated by biogas, or any other broader financial incentives to encourage technological adoption.

Barriers and risks

Table 99: Summary assessment of barriers and risks

Barriers						
Knowledge and information	Organization/ social	Regulations/ Institutions	Support services/ structures	Financial returns	Access /cost of capital	Risks
• There is a lack of qualified experts in the sizing, design, and safety of systems, particularly of engineers and technicians specialised in biogas • There is a lack of knowledge of new biogas technologies	• It is important to consider the characteristics of the local environment in project design and implementation	• There is a lack of regulations that require the energy recovery of biogas • There is no institutional framework to launch tenders for biogas projects • There is a complicated regulatory environment to launch projects • There is a lack of clear development strategy at the policy level	• There is a lack of support services for operation, maintenance and installation of plants • There is limited knowledge amongst public officials • There is a lack of university-level projects in biogas	• There is no preferential tariff for electricity generated by biogas • Competition is high from other energy sources, both renewable and conventional	• Lack of access to credit • Upfront investment cost very high	• The technology may incur negative water and food security implications if not deployed correctly

Source: Authors' compilation.

The limited penetration of biogas technology in Morocco can be accounted for by a number of barriers, above all at the regulatory and institutional level (Chaoui Roquai & Hartig, 2012). Currently, there is a lack of regulations that promote the recovery of energy from biogas, as well as an absence of an institutional framework and development strategy to issue projects and encourage technological adoption.

Furthermore, the current regulatory framework is difficult to navigate and hinders the implementation of biogas projects. Financial returns and the cost of capital pose another predominant obstacle, due to the fact that biogas plants could not likely recover investment costs given the high upfront investment costs, operating costs and general absence of a commercial use for co-generated heat. Additionally, there is no preferential tariff for electricity generated by biogas. Therefore, given these constraints, it is difficult for biogas-generated energy to compete with other energy sources and, in the absence of state support for generation, little incentive for investors to favour biogas over other RE production systems.

The deployment of biogas technology also suffers from serious knowledge and support service gaps. Due in part to the limited number of biogas projects in the country, there is a general absence of qualified experts in most areas of biogas project implementation, as well as a lack of support services for the installation, O&M of biogas plants. The shortage of technical expertise extends to higher education, where there are few projects exploring the benefits of this technology. Finally, as discussed in Step 3, although biogas provides an alternative to fossil fuels, the technology may incur negative water and food security consequences if not implemented correctly.

Key instruments/policies/drivers to overcome barriers

Table 100: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• Setting targets for generating energy from biogas could improve uptake	• Introducing a framework to support the development and deployment of biogas technologies could encourage market adoption	• Introduce a preferential tariff for electricity generated by biogas • Preferential access to credit/ subsidies for investors in biogas	• Pilot programmes with lead/ larger farmers for demonstration • Capacity development of public and private extension support services • Investments in R&D and training	*

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects the complexity of expected policy changes, institutional/administrative implications and/or budgetary implications: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

To encourage biogas development in Morocco, the government could devise a comprehensive national programme to support the development and deployment of the technology, accompanied by targets for generating energy from biogas. The achievement of national targets could be facilitated by the introduction of a preferential tariff for biogas-powered electricity, which could boost the technology's competitiveness vis-à-vis other energy sources. Another financial support mechanism could be introduced in the form of preferential access to credit or subsidies for investors developing biogas projects. To encourage the growth of local expertise and support services, investments could be developed for R&D and capacity development. Meanwhile, the benefits of the technology could be demonstrated by the launch of pilot programmes with larger farmers. Due to the relative underdevelopment of biogas in Morocco, these initiatives would require a high level of institutional reform and significant investments. Consequently, the policy reform intensity level for this technology is considered high.

Renewable energy systems

Diagnostics: policies and institutions

Table 101: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• 52% share of renewables in electricity generation capacity by 2030 • Energy savings target of 12% by 2020, 15% by 2030 of total energy consumption (at 2011 levels)	• Law n. 16-09, created ADEREE • Law 57-09, created MASEN • Law 16-08 on self-generation • Law 13-09 Renewable Energy development • Law 58-15 increases visibility for private investments in RE	• Numerous grants, access to credit available through different institutions • Exemptions for imported materials, etc. for RE projects	• Numerous R&D initiatives • National Energy Strategy • National Energy Efficiency Strategy

Source: Authors' compilation.

Morocco's high electricity prices, dependence on imported energy, and geographic/climatic attributes have spurred the development of an extensive national RE programme[152]. Overseen by the MEM, with support from institutions such as the Centre for the Development of Renewable Energies and the National Electricity Office, Morocco's renewables programme comprises a number of ambitious RE targets. The Moroccan National Energy Strategy sets a target of 42 percent of total capacity coming from renewables, including 2 GW of wind, 2 GW of solar

152 For more information on the subject, as well as information on renewable energy development in North Africa, see United Nations Economic Commission for Africa, Office for North Africa, 2012.

PV (14 percent of the target each) and 1.2 GW_{th} of SWH by 2020[153]. In 2015, the government announced its ambition to further increase its target to a 52 percent share of renewables in electricity generation capacity by 2030. Moreover, the Moroccan National Energy Efficiency Strategy works to promote improvements in energy efficiency, namely an energy savings target of 12 percent by 2020 and 15 percent by 2030 of total energy consumption compared to 2011 baseline levels.

These goals are supported by a number of key policies passed in the last several years, which have created new institutions and legislative support mechanisms to oversee the development of renewable energies, notably:

(i) Law n. 16.09 establishing the ADEREE (MEM, 2013), which contributes to the implementation of government policy in the energy sector and provides deployment roadmaps. Established in 2010, it manages national plans for each RE sector and supports national R&D related to RE and energy efficiency[154].
(ii) Law 57.09 created the MASEN in January 2010, an agency entrusted with coordinating the National Integrated Project for Solar Electricity Production (ONE, 2009). The Solar Integrated Projects target the development of solar power plants with a total installed capacity of 2 000 MW. At full capacity, the solar power plants will generate about 4 500 GWh, of which part will be exported. The project aims to provide 10 percent of Morocco's electricity needs. Moreover, the National Agency for Solar Energy has two other primary tasks: the development of training, technical expertise and promote R&D in the field of solar energy; and the development of PPPs and the generation of international investment in Moroccan solar projects.

153 Other major programmes include the Global Rural Electrification Programme in Morocco and the Development Programme of the Moroccan Market for Solar Water Heaters (PROMASOL). PROMASOL started with SWH for collective buildings in health, education, and tourism with a target of 100 000 m^2 by 2008, and succeeded in increasing the number of SWH systems from 56 000 m^2 in 2001 to 231 000 m^2 in 2008 and 350 000 m^2 in 2012. The programme aimed at developing local industry through comprehensive capacity building efforts and combined investment subsidies with bank loans, repayable through the electricity bill (IEA, 2015). The programme trained accredited SWH consultants and established SWH quality norms and testing; facilitated access to services and local bank financing by providing credit guarantees for investors; and implemented awareness raising activities (REN 21, 2013). It trained and certified over 200 installers and specialised companies, and generated an increase in the number of companies importing and/or manufacturing SWHs from 5 in 2002 to more than 40 in 2011. Following this success, PROMASOL2 was launched, aiming to implement 1.7 million m^2 of SWH by 2020 through the "Shemsi" programme, which will be capable of delivering around 1.2 GWh thermal capacity and is expected to create 13 000 new jobs.

154 In particular, ADEREE is responsible for the development of energy management policies and the realization of national and regional plans for renewable energy and energy efficiency. Specifically, its targets are to increase installed capacity to 4 GW from solar and wind and 42 percent of installed capacity from renewables by 2020, which will in practice equate to approximately 25 percent of power generation (IEA, 2015b).

The programme aims to achieve an annual CO_2 emissions reduction of 3.7 billion tonnes[155].

(iii) The law of self-generation (Law 16.08), which, in 2008, raised the ceiling for self-generation by industrial sites from 10 MW to 50 MW. It was conceived principally to support wind power, but applies also to other RE technologies (IEA/IRENA, 2015).

(iv) In 2009, the Renewable Energy Development (Law 13.09) law established core regulation mechanisms for the production and commercialisation of renewable energies (MEM, 2010). The law set up a RE deployment roadmap and includes specific targets for the second phase of the National Plan for the Development of Renewable Energies and Energy Efficiency (PNDEREE 2006-2012).

(v) Introduced in December 2015, law 58-15 modifies and complements law 13-09 by increasing visibility for private investors looking to invest in RE projects. It enables private RE producers to sell back up to 20 percent of excess energy produced annually to the national grid, and paves the way for the liberalisation of production within the medium- and low-voltage grid. It also increased the minimum capacity for projects producing electrical energy from water power from 12 to 30 MW[156].

(vi) Energy Efficiency Law 47.09, which was introduced in 2011 in order to increase the efficiency of energy consumptions and allow for related cost savings through, for example, the use of solar water heaters, energy saving equipment and low consumptions light bulbs.

Morocco is currently relying on both tendering and public investments in order to meet its targets. In addition to around 500 MW of RE projects that have been awarded power purchase agreements, another 850 MW of wind power and 300 MW of CSP are now in the tendering process (RCREE, 2015). Regarding fiscal measures and financial support, although the country has a relatively high corporate tax rate (30 percent) which may affect the incentive to invest in RE, it also has exemptions from customs duties for imported equipment, materials, and tools to be used for RE projects (RCREE, 2015). Moreover, Morocco has introduced a number of financial support institutions to facilitate investments in the sector, including the SIE[157], the Energy Development Fund (EDF) and the Renewable

155 According to law 57-09, MASEN responsibilities include: (i) elaborating on necessary technical, economic and financial studies for site qualification, design, construction and operation of solar projects; (ii) contributing to research and mobilising needed capital for solar projects; (iii) overseeing the realisation of infrastructure linking central infrastructure to ancillary infrastructure in accordance with regulations; and (iv) promoting the solar programme to national and foreign investors. The establishment of the MASEN has also favoured the deployment of other solar technologies such as solar CSP and PV projects, which have benefited from declining solar technology costs due to increased adoption and technological efficiency, coupled with the rising cost of conventional power sources.

156 See Medias 24, 2015.

157 Founded in 2010 by the Law of Finance (Law 40.08), the SIE is an investment fund for the energy sector to facilitate diversification of energy resources, promotion of renewable energy and energy efficiency.

Energy Fund (FER), which were established by the SIE to provide public funds to companies focusing on RE projects (RCREE, 2015)[158]. The sector also receives complementary support from various research initiatives, including IRESEN[159] and the Renewable Energy University Network (REUNET)[160]. Other institutions include the Moroccan Association of Solar and Wind Industries (*Association Marocaine des Industries Solaires et Eoliennes* [AMISOLE]), which promotes the interests of industries and Moroccan professionals in the RE sector[161].

Barriers and risks

Table 102: Summary assessment of barriers and risks

Barriers						Risks
Knowledge and information	**Organization/ social**	**Regulations/ Institutions**	**Support services/ structures**	**Financial returns**	**Access /cost of capital**	
• There is a need for additional training and technical expertise in usage of REs	• N/R	• Different green programmes at the regional and local level are not sufficiently integrated • Environmental legislation framework needs enhancement • Currently, restrictions on selling back to the grid may stymie investment	• Support of R&D, innovation, and training needs strengthening	• Investments are viable, but due to low margins there is a need for subsidies	• Lack of access to credit • Upfront investment cost very high	• Could lead to increased use of water

Source: Authors' compilation.

One of the most significant challenges to the deployment of RE technologies arises from a mixture of regulatory and institutional constraints. Due to the

158 Other financial support mechanisms include the FOGEER, which guarantees investment loans granted by leasing companies, businesses and Moroccan operators looking to invest in this area.

159 IRESEN was founded in 2009 to promote research, development and innovation of renewable energy technologies. It conducts and finances specific research projects and promotes networking among researchers, projects and universities to strengthen the knowledge capacity around renewable and low carbon technologies (WFC, 2015).

160 REUNET is a network founded in 2013 as a joint initiative of Moroccan academics, researchers and scientists in order to promote the use of renewable energy in Morocco through training, research and innovation. It is focused on solar energy, wind and hydro power, biomass and bioenergy, energy efficiency, energy storage, grid integration and power quality.

161 AMISOLE includes around 40 companies and brings together several hundred employees.

diversity of initiatives promoting RE targets, there is a need for increased integration between the wide variety of agencies and programmes available to efficiently achieve government objectives (MEM, 2012a). Without integration, this diversity creates challenges in accessing relevant information and data on state policies, objectives and other themes.

The effect of institutional barriers is exacerbated by a number of regulatory constraints, beginning with legislation surrounding the sale of excess RE back to the national grid. Although the Moroccan Parliament implemented several amendments in late 2015 to the RE law to increase visibility for private investments and facilitate the sale of excess energy on the high-voltage grid, several obstacles remain. For example, solar and wind power producers connected to the middle- and low-voltage grid are not yet able to sell back energy to the national grid. Additionally, private investors will only be able to sell back up to 20 percent of their annual production (SeeNews, 2016). Other regulatory issues include an environmental legislation framework that is in need of additional reforms and the absence of fiscal incentives to develop green professions and RE uptake, particularly in agriculture. Specifically, a 2012 report on the green economy revealed that there is a need for increased mobilisation of private investment, as well as initiatives in R&D and innovation (*Conseil Economique et Social*, 2012). The absence of a national programme to structure training and R&D is cited as a potential hindrance to the development of professions in RE-related industries.

Regarding financial returns, although some REs, particularly PV, are already competitive with conventional energy sources, margins are still low, therefore the cost of financing remains a potentially significant barrier to investment. Additionally, the findings in Step 2 on the financial viability of RE are based on the assumption that all energy produced can be consumed or sold to the national grid. However, with the current cap on the amount of electricity that private RE producers can sell back to the grid set at 20 percent, state subsidies constitute an important driver for investments. That said, electricity prices in Morocco are among the highest in the MENA region, therefore even at current energy prices, investments in many RE options are viable and the gradual elimination of fossil fuel subsidies will create additional opportunities (IFC, 2013).

Due to the relatively new introduction of RE technologies, the Moroccan market would also benefit from increased technical expertise and training amongst farmers and other sector participants in RE systems. Finally, the introduction of RE systems would entail mixed environmental outcomes: while this technology would decrease fossil fuel consumption, facilitate agricultural activities such as water pumping and electrification, and improve resilience to climate change, it could also lead to increased use of water, and potentially lead to the overexploitation of groundwater resources.

Key instruments/policies/drivers to overcome barriers

Table 103: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• Ambitious targets are already set and are driving sector development	• Better define regulations on the low- and medium-voltage grid • Better define institutional mandates	• Increase incentives for private investment	• Invest in R&D, innovation, and training schemes • Capacity development of public and private extension support services • Improve institutional and programme coordination	*

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects the complexity of expected policy changes, institutional/administrative implications and/or budgetary implications: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

Morocco's track record in supporting RE programmes has been generally successful, exemplified by its 2015 rank in the Arab Future Energy index (AFEX)[162]. The country placed first in the region, due in large part to a very high score in finance and investment support, subsidy-related policy and progress made in meeting its ambitious targets (RCREE, 2015). Additionally, the country's numerous achievements, including the construction of the world's largest solar plant in 2016, underline the government's emphasis on RE as a burgeoning source of economic growth. Morocco's various targets for the sector serve as a driver for the continued development of RE, but a number of issues could be addressed to promote further progress. For example, the state could better define the regulations governing the low- and medium-voltage grid – amendments that are expected in the coming months – as well as the mandates and responsibilities of newly created institutions and programmes. On this subject, the government could facilitate increased coordination between

162 The Regional Centre for Renewable Energy and Energy Efficiency (RCREEE), which aims to enable and increase the adoption of renewable energy and energy efficiency practices in the Arab region, has analysed Moroccan initiatives in these sectors. The AFEX 2015 provides an assessment of countries' progress in renewable energy according to four evaluation categories: its market structure, policy framework, institutional capacity, and finance and investment in RE (Figure 4.1.11.b).

institutions to improve the effectiveness of national, regional and local project implementation. The introduction of additional price incentives could also encourage private investment, while investments in R&D, innovation and capacity training would create new opportunities for economic and job growth. Given the level of institutional reform and capital needed to forward these objectives, the policy intensity for RE is deemed high.

Small dams

Diagnostics: policies and institutions

Table 104: Summary diagnostics of key policies

Targets	Regulations	Price incentives	Public expenditure
• Build 1 000 new small dams and lakes by 2030 • The technology is mentioned in the national communication, though there is more of an emphasis on large dams	• Revision of water law 10-95	• 80–100% subsidy on water storage basin projects for conventional irrigation	• There are PPPs for the construction of new dams • Projects under the PEI

Source: Authors' compilation.

Due to the scarcity of Morocco's water resources, effective water management has been a national priority since the 1960s, prompting a succession of proactive government programmes to support dam construction and management. National dam construction programmes receive institutional support from the General Directorate of Water (*la Direction Générale de l'Hydraulique*) and the PMV, and regulatory support from a number of entities, including the National Water Strategy (*Stratégie Nationale de l'Eau*), the National Charter for the Environment (*la Charte Nationale de l'Environnement*), and the National Communications of Morocco on Climate Change (*les Communications Nationales du Maroc sur les Changements Climatiques*)[163]. Dam projects also receive support from social R&D initiatives[164].

After experiencing a number of droughts during the 1980s, the Moroccan government began investing in small dams over large dams due to their

163 Other major institutions include: the *Secrétariat d'Etat Chargé de l'Eau et de l'Environnement*, which conducts execution studies and provides technical assistance during construction, among other tasks; and the Ministry of Interior, which provides some construction materials and pays the incomes of labourers.

164 For example, the National Programme for Expanding Access to Water in Rural Areas (*Programme National de Généralisation de l'Accès à l'Eau Potable en Milieu Rural*).

relatively low cost and short execution time. Since 1984, 74 small dams have been constructed in the country with a capacity of 400 million m^3. Small dams are generally constructed through PPPs, initially formed between foreign private companies and the state. However, domestic firms gradually obtained the necessary technical know-how and experience from foreign companies: by 2005, the majority of PPP dam construction projects were conducted with Moroccan firms, demonstrating the high level of training and technical expertise in the Moroccan workforce.

Morocco has set ambitious targets for the expansion of this technology and aspires to construct 1 thousand new small dams and lakes by 2030. The mobilisation capacity of these facilities is estimated to be 600 million m^3 (CMB, 2010). Already, 1 500 sites with technical and economic feasibility have been identified by the CMD, therefore there is considerable scope for further expansion. These initiatives will be complemented by projects implemented under the *Programme d'Extension de l'Irrigation associé aux barrages*[165] and the *Agence de Développement et de Promotion des Provinces du Sud du Royaume*, which has launched a programme to construct 94 small dams in 15 provinces in the coming years (CMB, 2010).

The government's targets are expected to be supported by the national water law No. 10-95, which is currently under revision to address regulatory gaps and deficiencies. According to Abdesslam Zyiad of the Office of Research and Water Planning (*la direction de la Recherche et de la Planification de l'Eau*) the revisions are expected to clarify a number of concepts and improve text on issues such as the exploitation of rainwater and wastewater and protection against floods (Quid, 2015). Targets may also receive indirect support from financial incentives available from the MAPM, which provide an 80–100 percent subsidy on projects for water storage basins for conventional irrigation, though the direct impact on dam construction will likely be negligible.

165 For a list of PEI projects, see AQUASTAT (2010).

Barriers and risks

Table 105: Summary assessment of barriers and risks

Barriers						Risks
Knowledge and information	Organization/ social	Regulations/ Institutions	Support services/ structures	Financial returns	Access /cost of capital	
• N/R	• There is insufficient management capacity by users' organizations	• The mandates for different institutions need clarification • There are limited water governance mechanisms	• N/R	• Investments require long-term commitment and have uncertain financial returns	• Upfront investment cost very high	• N/R

Source: Authors' compilation.

As discussed in Step 2, the main barriers for the uptake of small dams are related to financial returns and access to capital. Investments in small dams necessitate high investment costs, have long payback times and may not produce attractive financial returns, therefore the private sector would likely only consider this technology within the context of a PPP. Although there are additional economic and environmental benefits to be incurred, only the state has the resources and the flexibility to make an investment in small dams at the moment.

The construction of small dams is aided by strong technical expertise within the Moroccan workforce, which possesses knowledge of best international practices and currently exports its expertise to over a dozen countries in Africa and the Middle East. Morocco also enjoys a high level of support services for the construction and maintenance of dams. As a result, there is little scope for technological innovations due to the sophistication of the local industry. However, there are reportedly some deficiencies in dam management due to inadequate management of users' organizations and unclear mandates at the institutional level. The latter constraint is one of several gaps and deficiencies within the national water law No. 10-95 that policymakers are looking to amend.

Based on the analysis conducted in Step 3, small dams present few sustainability risks, and are reported to have a positive effect on trends in food and water security, while increasing resilience to drought. The technology also reduces energy consumption for water pumping, can be used to generate RE, and contributes to the restoration of degraded lands. Finally, small dams can have a positive impact on poverty by creating jobs in construction. The sustainability risks related to efficient manure management are not relevant as evidenced by the analysis in Step 3.

Key instruments/policies/drivers to overcome barriers

The previous analysis suggests that the policy environment surrounding the construction and maintenance of micro dams is fairly well developed, therefore there is relatively little need for further developing support services. Although the government has already set ambitious targets for sector development, the revision of the water law will likely prove important in clarifying the mandates and responsibilities of key institutions. This reform could therefore facilitate improvements in dam management and users' organizations. To mobilise additional financial resources, the state could consider introducing financial incentives such as tax breaks to encourage the participation of the private sector in dam investments. In sum, the aforementioned initiatives require relatively few reform and investment commitments, therefore the policy reform intensity of supporting the adoption of small dams in Morocco is considered low.

Table 106: Summary of relevant policy themes and assessment of policy reform intensity

Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
• The state has already set ambitious targets, which can help to signal government priorities and focus the scope of projects	• Revision of Law no. 10-95	• The provision of financial incentives could help encourage private investors to participate	• There is little need for further capacity development of extension support services	***

Source: Authors' compilation.

Note: The score reflects complexity of expected policy changes, institutional/administrative implications and/or budgetary implications: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

Discussion of Step 4 findings

Despite the diversity of technologies, there are a number of common trends that emerge from examining barriers to the adoption of climate smart technologies. First, a lack of farmer knowledge is an obstacle faced across the board for the selected technologies and practices, suggesting that there is considerable scope for training initiatives to increase awareness about more climate efficient technologies and the appropriate way to use them. To a lesser extent, there is also a shortage of qualified experts to assist in the deployment of certain technologies, such as biogas plants, a problem that could be attributed in part to a relatively low penetration rate. This may also account for a shortage of adequate support services for specific technologies, such as in the case of grazing management. In other instances, support services exist or could be altered with relatively little difficulty to encourage adoption, with efficient field machinery being an example.

As discussed in Step 2, financial returns can also serve as a major obstacle to the adoption of the majority of selected technologies. Many have high upfront costs that smallholders may not be able to afford. Although a few technologies are eligible for grants and subsidised loans, a lack of access to credit is a challenge faced by farmers across technologies. Consequently, it is often only large-sized farms that possess the capital to acquire new technologies without subsidies. However, this barrier is not unique to technology adoption or to Morocco itself, as farmers in many developing countries are unable to acquire credit.

In the wake of ambitious programmes such as the PMV and the National Energy Strategy, the Moroccan government has made notable progress in expanding the breadth of its legislation overseeing the uptake of climate smart technologies. However, there is considerable scope for improved legislation and institutional coordination within the domain of water governance and land tenure. Currently, regulatory and institutional limitations in water governance have had a significant impact on the deployment of drip irrigation and solar and wind-powered pumps, while grazing management uptake has been complicated by issues with land rights. There is also scope to further develop legislation, targets and support mechanisms for certain technologies that have received less policy backing, such as manure as soil amendment, efficient water boilers and biogas. However, the absence of policies suggests that these technologies have not yet been identified as priorities for CCA and mitigation. Nevertheless, this may change in the coming years, thereby positively affecting technological uptake.

The adoption of certain technologies may also be slowed due to current policies that indirectly encourage the use of conventional fossil fuels. For example, although the Moroccan government has recently eliminated a number of energy subsidies, price supports for butane gas remain in place, creating direct competition for solar and wind-powered pumps and biogas. Additionally, butane subsidies may indirectly hinder the implementation of efficiency measures for cold storage by reducing the financial appeal of such measures.

These trends have implications for appropriate policy packages to promote technology uptake. For example, policymakers can better understand where the establishment of targets may have helped adoption (i.e. drip irrigation, solar and wind pumps, RE systems, and small dams) and where additional targets can be introduced to encourage penetration (CA, efficient field machinery; grazing management; manure as soil amendment; livestock breeds and improved diets; efficient boilers; efficient cold storage; and biogas).

Building on the previous discussion of regulatory limitations, the proposed reforms to the water law 10-95 and a new groundwater law could encourage the adoption of drip irrigation, solar and wind-powered pumps, and small dams by addressing concerns over groundwater exploitation and other water governance issues. Similarly, the passage of stronger land rights regulations could facilitate grazing management practices, while the removal of butane and fuel oil subsidies could increase the cost competitiveness of solar and wind-powered pumps, efficient boilers and efficient cold storage. Finally, the general strengthening of governance over issues related to manure as soil amendment (i.e. manure management), efficient boilers (i.e. the standardisation of boiler regulations) and biogas (i.e. a framework to encourage uptake) could enhance the appeal of these technologies to agricultural sector participants.

More broadly, the vast majority of technologies could benefit from increased public expenditure and price incentives. Proposed public support varies by technology: for some, promoting pilot programmes could demonstrate their potential to farmers (CA, grazing management, livestock dairy breeds, and biogas), while increased capacity development for public and private actors and support services could provide needed training for most of the selected technologies. Price incentives also vary: for example, introducing a preferential tariff for technologies using renewable energies could improve the financial returns of biogas plants, while subsidies and other incentives could reduce high upfront investment costs for most technologies, ranging from RE systems to efficient field machinery.

In sum, the three primary barriers to the adoption of climate smart technologies in Morocco are financial attractiveness, regulatory/institutional issues, and access to credit and the cost of capital. A lack of farmer training and awareness is also an important obstacle to overcome to encourage increased technological uptake. Issues related to social and organizational barriers (including social norms and behaviours, collective action) as well as support services and structures (local research, the coverage and efficacy of maintenance companies, etc.) appear to pose fewer constraints. Nevertheless, the diversity of technologies necessitates a case-by-case approach to effectively understand the barriers to uptake and the potential solutions to promote adoption.

Conclusions and recommendations

On the basis of the analysis, it is possible to draw some conclusions about the key sustainable climate technologies and practices of the Moroccan agrifood sector that show high potential for market development and would therefore provide "more bang for the buck" from the point of view of an institutional investor or a decision-maker in the area of sustainable development (e.g. the government, a multilateral development organization or a donor).

Step 1 of the methodology highlighted the most relevant areas of intervention for mitigating GHG emissions from the agriculture and food industry sector. Steps 2 and 3 assessed the techno-economic performance and the sustainability concerns and synergies (including with climate adaptation) of a number of technologies and practices in the national context. Finally Step 4 reviewed the key policies, barriers, and risks associated with each technology or practice under analysis and suggested possible policy interventions to spur market adoption. A score associated with the overall policy reform intensity to overcome the policy barriers identified was provided for each technology. This analysis can be replicated over time, and extended to additional technologies or practices as convenient. It can also be performed in other countries for an inter-country comparison of the most promising climate technology in each of them.

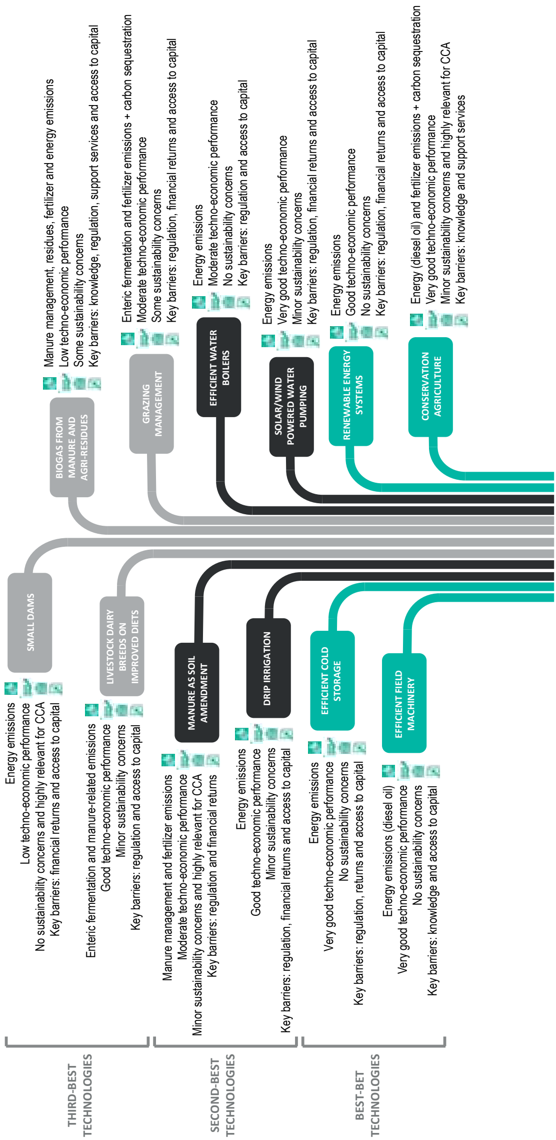
The technologies are classified in three main groups: best-bet technologies, second-best technologies and third-best technologies. These classifications were drawn from a market development potential point of view, having climate change mitigation (GHG emissions reduction) potential as its primary lens and taking into consideration economic, market and technical criteria, as well as environmental and socio-economic concerns/co-benefits. The classification of the 12 analysed technologies into these groups is reported in Figure 44, along with a short summary of the results of the four-step assessment.

The technologies in the lower part of the figure can be considered "low-hanging fruit"; that is, climate technologies with considerable mitigation potential which imply no or insignificant trade-offs and face relatively low barriers to further adoption. These can be seen as easy wins by financing institutions and policymakers.

In general, the technology groups are the result of the weight and priorities given to each indicator in this analysis and results might change if the assessor decides to see the results through different lenses. For instance: (i) efficient boilers or grazing management do not imply heavy trade-offs and should be considered for support, as the former seem to bring relatively low no particular implementation burdens and the latter, if implemented successfully, will generate incommensurable environmental and social benefits; (ii) drip irrigation, small dams and improved grazing management are important technologies for CCA and must be supported if that is the main aim; and (iii) manure as soil amendment, improved livestock breeds and diets and biogas from manure and agri-residues, regardless of their classification, all need further piloting and studies before definitive conclusions on their sustainability, feasibility or adequate policy measures are taken.

Again, it should be highlighted that the number of possible technologies is not limited to these 12, and that the selection was done on the basis of expert consultation trying to prioritise those technologies that could bring the most benefits in terms of GHG emission reduction in the agrifood sector while maximizing co-benefits. The results would have been significantly different if the selection of technologies had prioritised solutions with other main purposes.

Figure 44: Summary of results of the four-step assessment.



Source: Authors' compilation.

Note: The technologies/practices towards the bottom of the "tree" are those holding more potential in terms of market penetration in Morocco ("low-hanging fruit").

A number of possible policy interventions are suggested in Step 4 to unlock the existing barriers to market penetration by technology. They relate to setting targets, regulation, price incentives and public expenditure. Table 107 summarises the identified policy intervention categories that could facilitate the further market development of the technologies under analysis. In general, it can be said that the principal obstacles to the adoption of the climate technologies discussed in this study are due to:

- access to credit and cost of capital
- financial attractiveness
- regulatory and institutional issues

Since not all policy interventions are equally easy to implement in a given context, an assessment of the complexity of the expected policy changes, institutional/administrative implications and/or budgetary implications is made in the last column on the basis of expert opinion. The results provide an indication of the "policy reform intensity" for each technology or practice in Morocco. This policy reform intensity is expressed with a rank of one to three stars and provides a rough evaluation based on expert opinion of the expected effort associated with changes to current policies and/or the largest public support measures (including financial allocations) for adoption.

Table 107: Identified policy intervention categories to unlock the existing barriers to market penetration in Morocco and policy reform intensity

Technology	Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
Conservation agriculture	• Can help signal CA as a policy priority	• N/R	• Subsidy may not be required if support to rental market for direct seeders • Rebalancing of support policies can promote rotations	• Pilot programmes with lead/larger farmers for demonstration • Capacity development of public extension and private extension support services	**
Efficient field machinery	• Set a target for the number of tests to be conducted per year	• N/R	• The state could initially support bench testing through subsidies (in particular for poorer farmers)	• Awareness campaigns • Equip technical visit centres with appropriate testing equipment	**

Technology	Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
Drip irrigation	• Positive track record with drip irrigation uptake	• Implement a comprehensive groundwater law and revise Law 10–95	• Promote drip irrigation alongside interventions in water use monitoring and pricing	• Provide farmer training programmes that can also unify smallholders into organized units	**
Solar/wind pumps	• Aforementioned state targets for RE pump installations: broader RE goals for sector	• Removal/ reduction in butane subsidies • Implementation of a water governance law	• Attribute RE pump investment grants • Introduce a system wherein farmers can sell back unused renewable energy to the grid	• Campaigns to spread awareness • Facilitate access to credit for RE users • Capacity development of public and private players, extension support services	*
Grazing management	• Track record and communicate achievements on the targets for implementing improved grazing practices in applicable environments	• Better define land status on collective grazing lands, and clarify administrative boundaries	• Expand the reach of subsidies for initial investments and technical assistance	• Pilot programmes with lead/larger farmers for demonstration • Capacity development of public and private extension support services • Reinforce cooperatives	**
Manure as soil amendment	• Targets on efficient management of agricultural waste products can provide a signal along with existing targets for household waste and others	• Certification and clear norms on compost can support market development • Regulations on manure management could support technology adoption but would translate into costs	• Manure management would require incentives to internalise externalities	• Increased spending on enforcement of correct disposal of agricultural waste • Studies and data collection focusing on soil fertility management and bio-fertiliser alternatives	*

Technology	Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
Livestock dairy breeds on improved diets	• Setting specific targets for adoption of purebreds and improved diets could help this technology gain traction	• N/R	• N/R	• Pilot programmes with groups of farmers to illustrate benefits • Capacity development of extension services and farmers	**
Efficient boilers	• Setting targets for minimum maintenance standards could aid uptake	• Introduce a policy and regulatory framework to support the standardisation of boilers	• Support upfront investment costs • Removing fuel oil subsidies will likely help support technological adoption	• Support implementation of energy efficient boiler adoption projects and manufacturing • Capacity development of public and private extension support services	**
Efficient cold storage	• Introduce targets for the adoption of efficient cold storage equipment and energy efficiency targets for the industry	• N/R	• Revision of butane subsidies • Potentially expand state subsidies for improvements	• Awareness campaigns and farmer training • Capacity development of public extension and private extension support services	**
Biogas from manure and crop residues	• Setting targets for generating energy from biogas could improve uptake	• Introducing a framework to support the development and deployment of biogas technologies could encourage market adoption	• Introduce a preferential tariff for electricity generated by biogas • Preferential access to credit/ subsidies for investors in biogas	• Pilot programmes with lead/larger farmers for demonstration • Capacity development of public and private extension support services • Investments in R&D and training	*

Technology	Targets	Regulations	Price incentives	Public expenditure	Policy reform intensity
Renewable energy systems	• Ambitious targets are already set and are driving sector development	• Better define regulations on the low and medium-voltage grid • Better define institutional mandates	• Increase incentives for private investment	• Invest in R&D, innovation, and training schemes • Capacity development of public and private extension support services • Improve institutional and programme coordination	***
Small dams	• The state has already set ambitious targets, which can help to signal government priorities and focus the scope of projects	• Revision of Law no. 10–95	• The provision of financial incentives could help encourage private investors to participate	• There is little need for further capacity development of extension support services	***

Source: Authors' compilation.

Note: For the column "policy reform intensity", the score reflects: * ranks low: needs high intensity of reform while *** ranks high: needs little / low intensity of reform.

The results from the application of the four step methodology to the Moroccan context show that CA, efficient field machinery, RE systems and efficient cold storage can be considered "low-hanging fruit" solutions to reduce GHG emissions from the agrifood sector while maximising co-benefits and minimising negative impacts on other sectors.

The identified policy interventions that could further spur the market penetration of these technologies would imply a medium to low intensity of reform. They could therefore be prioritised when choosing among a number of possible options. These technologies/practices are followed by solar and wind-powered water pumping, drip irrigation, efficient water boilers and manure as soil amendment. However, within this second group, solar and wind pumps and manure management are deemed to require a higher intensity of policy reform in order to be able to safely attract investments and increase their market penetration. Finally, grazing management, livestock dairy breeds on improved diets, biogas and small dams would require more targeted support in Morocco's current context, since their market development potential appears to be constrained for different reasons. This does not mean they should not be supported in the country but, on the contrary, they would require a more holistic support framework in order to overcome the barriers that hinder their full deployment (be they technical, economic, social, or regulatory), and/or to put in place all the social or environmental safeguards needed to avoid undesired negative effects.

Limitations of the study and further research

The type of assessment undertaken in the framework of this study is limited by definition. The present exercise was performed with very limited non-public data, complementing quantitative analysis with more qualitative considerations and the opinions of local experts.

The assessment should therefore be interpreted with caution since, although the purpose is to provide information as correct as possible on the criteria for each technology, in many cases further location or case-specific analysis is needed to achieve more conclusive results.

The step-by-step methodology used here was formulated with the purpose of addressing the need for reducing GHG emissions in the agrifood sector, while maximising co-benefits such as the more efficient use of natural resources or improved livelihoods of the rural population. CCA is included as a criterion impacting the classification of technologies, but it is not the primary focus of the assessment. For this reason, technologies such as small dams, biogas from agri-residues, or grazing management, which have important value in making agriculture more resilient to climate change, rank relatively low compared to other technologies. Hence the methodology applied here is mostly meant to screen technologies with potential to attract climate financing to mitigate emissions while maximising co-benefits more than prioritising technologies and measures for CCA.

The criteria used for the techno-economic and sustainability analysis are measured by applying quite general and large thresholds for the indicators (for example a GHG mitigation potential of less than 3 percent, between 3 percent and 20 percent or over 20 percent of the total agrifood GHG emissions). In this way, errors are minimised, although such errors would have a limited impact on the overall results of the MCA of Steps 2 and 3.

The analysis above, and the barriers and policy analysis performed in Step 4, therefore provide valuable insights into the market and market potential of climate technologies. These tools and information can be used by financing institutions, governments and other stakeholders to conduct a quick appraisal and to identify needs for further analysis associated with specific investments, be they countrywide technological changes (e.g. the establishment of a new financial mechanism to promote the uptake of efficient water boilers, a change to an existing regulation limiting underground water use due to solar irrigation, the introduction of efficiency testing benches for field machinery, etc.) or project specific. Such detailed analysis lies outside the scope of this study.

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Annex I: Technical coefficients and other parameters used in this study

Table 108: GHG emission factors by fuel

Energy carrier	Emission factor (EF)
	$kgCO_2eq/TJ$
Diesel:	74 391
Fuel oil:	77 628
Butane (LPG):	63 307

Source: MDCE, 2016.

Note: Other GHG emission factors are consistent with IPCC, 2006.

Table 109: Country GHG emission factors for electricity, 1990–2013

	1990	1995	2000	2005	2010	2012	2013
				gCO_2/kWh			
Electricity (Morocco)	794	943	846	843	695	708	642

Source: IEA, 2016.

Note: The 3rd National Communication of Morocco to UNFCCC adopted a country emission factor for electricity of 729 gCO_2eq/TJ in 2012 (MDCE, 2016) and this latter value was used in this document for the assessment of the economic criteria and the mitigation potential of Step 2.

Table 110: Prices of energy carriers

Energy carrier	Price
	USD/GJ
Diesel:	29
Fuel oil:	12
Butane (LPG):	6.9
	USD/KWh
Electricity	0.11

Source: Authors' compilation.

Table 111: Energy density of fuels

Energy carrier	Energy density	
	value	*unit*
Diesel	9.72	kWh/litre
Fuel oil	10.36	kWh/litre
Butane (LPG)	13.75	kWh/kg

Source: MDCE, 2016.

Other fuel-specific physical-chemical characteristics of fuels are taken from *IEA, 2005. Energy Statistics Manual*, available online at https://www.iea.org/publications/freepublications/publication/energy-statistics-manual.html

Table 112: Other economic and financial coefficients

USD:MAD exchange rate	0.1
Social discount rate	8%
Financial discount rate	12%

Source: Authors' compilation.

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