Food and Agriculture Organization of the United Nations

European Bank for Reconstruction and Development

Egypt, Turkey and Ukraine

Sustainable bioenergy options from crop and livestock residues

COUNTRY HIGHLIGHTS

FAO INVESTMENT CENTRE

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FOREWORD

The European Bank for Reconstruction and Development (EBRD) and the Food and Agriculture Organization of the United Nations (FAO) are fully committed to helping countries and communities adapt to a changing climate, and to reducing the agrifood sector's environmental footprint.

The EBRD devotes a significant share of its portfolio to improving energy efficiency and energy savings in the countries where it invests in order to reduce production costs, enhance competitiveness, support energy security and lower greenhouse gas (GHG) emissions. This is part of the Bank's efforts to increase its volume of green financing to 40 percent of its annual business investment by 2020. FAO continues to step up its efforts to make agriculture, forestry and fisheries more productive and sustainable while also safeguarding the earth's natural resources. To better assist its member countries in addressing climate change and in achieving the Sustainable Development Goals, the Organization recently created a dedicated department for Climate, Land and Water.

As countries strive to meet their growing energy needs, they are increasingly turning toward renewables – such as biomass and hydro, wind and solar power – in the hope of becoming more energy secure and less dependent on expensive fossil fuels. Given that many countries generate large volumes of crop and livestock residues annually, one promising option is to transform those unused residues into bioenergy for heating, cooking and electricity.

This report looks at the different sustainable bioenergy options from agricultural residues in Egypt, Turkey and Ukraine. The work is part of the EBRD's Green Economy Transition (GET) Approach and builds on FAO's Bioenergy and Food Security (BEFS) approach.

The longstanding partnership between FAO and EBRD will continue to draw on the strengths of both institutions to help countries build resilient agriculture and food systems and adopt innovative climate-smart technologies and practices to produce more with less.

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The Energy Team of the Climate and Environment Division (CBC) of FAO led the technical implementation of the study under the supervision of Irini Maltsoglou, Natural Resources Officer, FAO, and the overall leadership of Olivier Dubois, Senior Natural Resources Officer, FAO.

The authors of this report are Irini Maltsoglou, Luis Rincon, Bioenergy and Food Security (BEFS) Techno-Economic Lead Expert, Ana Kojakovic, Natural Resources Officer, Duska Sasa, Lead Bioenergy Expert, Manas Puri, Sustainable Energy in Agriculture Expert, Patrizia Monteduro, Natural Resources and GIS Specialist of CBC, Evren Yaylaci, Environmental and Resources Management Expert, with support from Federica Chiozza, Pia Dahdah, Sergio Rivero, Vicki Romo, Simona Sorrenti, and Chengyi Wu, all members of the BEFS Team, CBC, FAO. Alessandro Flammini, Natural Resources Officer, and Arianna Carita, Economist, of the Investment Centre of FAO supported the editing of this report.

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ACRONYMS AND ABBREVIATIONS

ARC	Agriculture Research Centre
ARST	Academy of Scientific Research and Technology
BEFS	bioenergy and food security
BSG	brewers' spent grain
CAPMAS	Central Agency for Public Mobilisation and Statistics
CBC	Climate and Environment Division
CHP	combined heat and power
E2C2	Energy Efficiency and Climate Change
EBRD	European Bank for Reconstruction and Development
EIA	U.S. Energy Information Administration
EPDK	Energy Market Regulation Authority
FAO	Food and Agriculture Organization of the United Nations
FAO SEC	FAO Subregional Office for Central Asia
FiT	feed-in tariff
GET	green economy transition
GDP	gross domestic product
GHG	greenhouse gas
LHV	lower heating value
LPG	liquefied petroleum gas
NDC	nationally determined contribution
NREA	New and Renewable Energy Authority
NREAP	National Renewable Energy Action Plan
RA	Rapid Appraisal
REU	FAO Regional Office for Europe and Central Asia
RNE	FAO Regional Office for the Near East and North Africa
SBP	sugar beet pulp
SEC	Scientific Engineering Centre
SSF	Shareholder Special Fund
TAGEM	General Directorate of Agricultural Research
TKDK-IPARD	Authority for Assisting Agricultural and Rural Development
YEGM	General Directorate of Renewable Energy

EXECUTIVE SUMMARY

Bioenergy can play an important role in country-level climate change mitigation strategies. Bioenergy is derived from biomass, which can be deployed as solid, liquid and gaseous fuels for a wide range of uses including heating, electricity production and cooking. It can also provide substantial climate change mitigation benefits when developed sustainably and therefore can be instrumental in working towards the achievement of the Paris Agreement goals.

The Bioenergy and Food Security (BEFS) Approach of FAO helps countries design and implement sustainable bioenergy policies and strategies by ensuring that bioenergy development fosters both food and energy security, and that it contributes to agricultural and rural development in a climate-smart way. It consists of tools and guidance to support countries through the main stages of the bioenergy policy development and implementation process. For instance, the BEFS Rapid Appraisal (RA) consists of a set of easily applicable methodologies and user-friendly tools which allow countries to get an initial indication of their sustainable bioenergy potential and of the associated opportunities, risks and trade-offs.

In the case of the Egypt and Turkey assessments, the tools and methodology of the BEFS approach, including the Sustainable Biomass Assessment and the BEFS RA tools were used. The bioenergy value chains that were analysed include crop and livestock residues for the production of heat, power or combined heat and power (CHP). In Egypt, the analysis was carried out at governorate level, while in Turkey the assessment was carried out at province level. The assessment reports indicate which crop or livestock bioenergy chains are potentially most profitable and where the different feedstock sources are located.

The biomass assessment for Egypt highlights that:

- In terms of crop residues, maize stalks, rice straw, sugarcane bagasse and cotton stalk are the most readily available. Maize stalk, rice straw and cotton stalk are most present in the Middle Delta region, while sugarcane bagasse is most present in the Upper Egypt region.
- The use of the pruning residues could represent a viable energy alternative for the northern Sinai region and pockets of the desert governorates. However, collecting prunings could be a technical and economic challenge.
- In terms of livestock residues, the availability is very limited due to the reported availability shares (0 percent for chicken manure, 25 percent for cattle manure).

Building on the estimates of the amount of available biomass and considering specific conditions (as outlined later in the report), the following conclusions were drawn:

(i) CHP (both from direct combustion and anaerobic digestion) can contribute approximately 7 percent to Egypt's overall renewable energy target for 2020. This is dependent on the amount of biomass identified as available (i.e. biomass produced that can be used for energy, once all current uses are accounted for) and can be significantly constrained by the accessibility of residues (i.e. biomass that can actually be accessed and used for the production of bioenergy, considering aspects such as collectability and mobilisation of the biomass).

- Briquettes and pellets could partially substitute liquefied petroleum gas (LPG) use. If all biomass estimated to be available from crop residues were to be used for the production of pellets and briquettes, this energy option would substitute 31 percent of current LPG consumption.
- Biogas production at an industrial level does not seem a feasible option due to the limited availability of suitable residues.

The biomass assessment for Turkey evidences a strong differentiation between collected residues and residues spread in the field and highlights that:

- The most readily-available residues are sunflower head, maize cob, maize husk, rice husk and hazelnut husk. The Marmara, Mediterranean and Central Anatolia regions have the largest amounts of collected residues in Turkey.
- Residues that are spread in the field and have high availability include cotton stalk, sunflower stalk and maize stalk. These are mostly located in Southeast Anatolia and the Mediterranean region.
- The collection and mobilisation of residues spread in the field can be expensive and challenging, requiring considerable logistics and coordination among farmers and processing plants.
- For livestock, the East and Central Anatolia regions have the largest share of cattle manure in the country.
- The highest production of chicken manure from both layers and broilers was found in the Aegean, Marmara, Central Anatolia and Black Sea regions.
- Disaggregating chicken manure production into layers and broilers shows comparable quantities for each group. The Central Anatolia and Aegean regions have the largest production of layer manure while the Marmara, Black Sea and Aegean regions have the largest production of broiler manure.

The results from the assessment in Turkey, based on the targets set out in the country's renewable energy policy, show that:

- In terms of electricity and under a specific set of assumptions, a combination of CHP schemes can meet 101 percent of the 2023 electricity target from biomass. This can be achieved by combining direct combustion of groundnut husk, pistachio shell, hazelnut husk, maize cob and maize husk and anaerobic digestion of cattle manure and sunflower heads.
- There is potential to meet considerable heat demand through bioenergy technologies from residues under the specific assumptions made in the analysis. In the example of cotton stalk, around 2.6 million tonnes of oil equivalent (Mtoe) of heat demand could be met depending on actual accessibility (versus 3.6 Mtoe for heating/cooling).

In the case of Ukraine, a full BEFS assessment was not conducted but a review of recent bioenergy studies on agricultural residues for bioenergy production was carried out to provide a background understanding of the bioenergy potential and context.

The analysis highlights that crop residues have the most significant energy potential and the estimated availability, regardless of the source, is significantly larger than the 2020 heat target from solid biomass, and equivalent to 203 petajoules (PJ). Processing residues can be used in several different energy production pathways and the most common is currently biogas from anaerobic digestion. The availability of livestock residues is not completely clear and would require further research in order to confirm previous assumptions and estimates.

Overall, the potential to use agricultural residues for biomass is highest in central Ukraine, while the lowest potential is located in the western provinces.

Chapter 1 – Introduction

In November 2016, the historic Paris Agreement came into force and a number of countries committed to keeping the average global temperature rise below 2 °C compared to pre-industrial levels by 2100, with a goal of 1.5 °C. Many countries have already outlined their time-bound strategy to limit their carbon emissions in their nationally determined contributions (NDC). Given that around two-thirds of greenhouse gas (GHG) emissions arise from the production and consumption of energy (IPCC, 2014), it is imperative to identify and implement technologies that enable countries to transition from fossil fuel-based energy to low-carbon renewable energy to fulfil the Paris Agreement.

Bioenergy is derived from biomass, which can be deployed as solid, liquid and gaseous fuel for a wide range of uses including heating, electricity and cooking. It can also provide substantial climate change mitigation benefits when developed appropriately and therefore can be instrumental in working toward the attainment of the Paris Agreement goals.

Context of the assignment

The work summarised in this report was developed under the collaboration between the European Bank for Reconstruction and Development (EBRD) and the Food and Agriculture Organization of the United Nations (FAO). It builds on the Bioenergy and Food Security (BEFS) Approach of FAO[1] under its Sustainable Bioenergy Support Package; and contributes to the EBRD's Sustainable Resource Initiative[2] under its new Green Economy Transition (GET) approach.

The EBRD's Sustainable Resource Initiative supports policy dialogue by working with governments to strengthen institutional and regulatory frameworks that incentivise sustainable energy investments; and looks at options to help transition economies increase their use of renewable energy. Amongst the renewable energy options, agricultural residues are an important consideration.

The BEFS Approach and, within it, the BEFS Sustainable Biomass Assessment are core elements of FAO's Support Package to Decision-Making for Sustainable Bioenergy.[3] The BEFS assessment is intended to provide a basis for the bioenergy policy process by identifying which bioenergy options are feasible

1 Please see http://www.fao.org/energy/bioenergy/bioenergy-and-food-security/en/.

2 Please see http://www.ebrd.com/what-we-do/sectors-and-topics/sustainable-resources-and-climate-change/sri.html.

3 For more information, see http://www.fao.org/energy/bioenergy/en/.

within a given country, based on the country context as well as its energy and agricultural requirements.

The work was implemented in close collaboration with national stakeholders.[4]

The document is divided in two parts. Part A assesses the potential to produce renewable energy from agricultural residues (crop and livestock residues) in Egypt and Turkey. Part B reviews the status of existing bioenergy assessments and potential in Ukraine.

Scope and structure

This document presents a summary of the BEFS assessments carried out in Egypt and Turkey and a summary of the review carried out in Ukraine.

The scope of the Egypt and Turkey assessments was to provide an initial assessment of the availability and potential use of agricultural residues for the production of heat, power or combined heat and power (CHP). The specific agricultural residues covered in detail are crop and livestock.

To conduct this assessment, the tools and methodology of the BEFS Approach including the Sustainable Biomass Assessment and the BEFS Rapid Appraisal (RA) tools were used. Country-specific data and conditions were used for the analysis. In Egypt, the analysis was carried out at governorate level, while in Turkey the assessment was carried out at province level.

Full details of the BEFS assessment in Egypt and Turkey can be found in the country reports.

In the case of Ukraine, the work focuses on a review of recent bioenergy assessment studies and the potential next steps to be undertaken in this context.

4 A full list of the stakeholders can be found in the full country reports BEFS Assessment for Egypt available from: http://www.fao.org/3/a-i6684e.pdf and BEFS Assessment for Turkey available from: http://www.fao.org/3/a-i6480e.pdf.

Chapter 2 – Part A: BEFS assessment for Egypt and Turkey

BEFS assessment methodology: biomass and energy end use options assessment

The BEFS assessment methodology follows that of the BEFS Sustainable Bioenergy Assessment.[5] The first step of the BEFS assessment is to review the country context, with a focus on the agriculture and energy contexts. The biomass assessment and the energy end-use options assessment screen results against the country context and conditions.

The main objective of the biomass assessment is to estimate the potential of agricultural residues for energy production and their geographical distribution within the country. Two main agricultural residue types were considered for the cases of Egypt and Turkey: crop residues, which include pruning, and livestock residues.

The estimate of residue availability was based on data obtained through technical consultations with national experts. At this level of assessment, the focus was on estimating the production and availability of agricultural residues at governorate/province level.

The main methodological approach includes 3 basic steps:

(i) assessment of the *production* of residues: estimate of the total amount of residues generated as a result of agricultural production at country and governorate/province level;
(ii) assessment of the *availability* of residues: estimate of the proportion of total residues produced that can be used for energy, once all current uses are accounted for;[6]
(iii) assessment of the *accessibility* of residues: estimate of the amount of available residues that could actually be accessed and used for the production of bioenergy, considering aspects such as collectability and mobilisation of the biomass.

5 A full overview of the BEFS Sustainable Bioenergy Assessment Methodology can be found at http://www.fao.org/energy/bioenergy/befs/assessment/en/.

6 Residues are often used as feed for animals or as mulch.

Production and availability of residues are covered by this study, while their accessibility is briefly discussed in general terms.[7]

The biomass assessment was followed by the energy end-use options assessment, which evaluates the viability of the selected bioenergy technologies,[8] namely direct combustion and biogas-based CHP as well as briquettes and pellets. The aim of this part of the assessment was to identify the potentially profitable and technically feasible combinations of energy production based on ranges of analysis identified from the availability, energy potential[9] and feedstock costs.[10] Comparing the ranges for these three specifications for each agricultural residue allowed for an estimate of the energy that might be profitably generated from available residues.[11]

In addition, the assessment quantified the extent to which these options could help meet the related renewable energy targets or the potential use of biomass as a heating or cooking alternative. The final results of the assessment show which option could be most profitable for which location. For a full overview of all the analysis steps and assumptions, please refer to the detailed country studies.

Egypt assessment

Scope of the assessment

Egypt has a large agricultural sector and aims to produce 20 percent of its electricity from renewable energy sources by 2020. There is a growing interest in Egypt to reduce fossil fuel imports and to find substitutes for cooking fuels, such as liquefied petroleum gas (LPG). Considering the country context and national targets, this analysis focuses on the use of available crop and livestock residues for the production of briquettes, pellets, and CHP from direct combustion or biogas. The analysis is based on country-specific data and conditions, and is carried out at governorate level (Table 1).

7 Quantifying real accessibility requires that the specific bioenergy development being screened to be at feasibility level so that the location and specifics of the supply chain are defined.

8 These technologies were selected through technical discussions and in agreement with national counterparts, FAO and the EBRD.

9 energy potential, as used in this study to refer to the lower heating value (LHV).

10 Due to the uncertainties of current market prices for agricultural residues, the collection costs were used as the primary indicator of a residue's price. These prices were calculated for each feedstock based on location, mechanisation of collection, labour intensity and the residue yields.

11 At this level of analysis, estimates are still indicative as availability and accessibility need to be validated at the local level, including local conditions that might affect technology aspects of the supply chain.

Table 1: Crop and livestock residue types selected in collaboration with Egyptian stakeholders for the analysis[12]

Residue type	Crop or livestock from which the residues is generated
Straw	Wheat, rice, broad bean, barley, flax, lentil
Stalks	Maize, cotton, sorghum, sesame, sunflower
Pruning	Citrus/orange, palm dates, grapes, olives
Haulms	Sugar beet, peanuts, soybeans
Bagasse	Sugarcane
Manure	Chicken and cattle

Source: Authors.

Note: The crop residues include residues spread in the field, collected in the field and collected in the processing facility. Livestock residues include manure from cattle and chicken.

Country context

The agricultural sector in Egypt plays an important role in the national economy, contributing 14.5 percent to gross domestic product (GDP) in 2014 and employing more than one-quarter of the labour force in 2013 (World Development Indicators, 2016; El-Nahrawy, 2011). Given the large scale of agricultural production, considerable volumes of residue are thus generated yearly, 52 percent of which is burnt in fields or inefficient burners (Nakhla et al., 2013). This has both environmental and climate implications. Egypt is among the 11 fastest-growing GHG-emitting countries in the world (Climate Investment Funds, 2016). The energy sector is the prime driver of GHG emissions in Egypt and accounted for 74 percent of all emissions in 2012; followed by agriculture, which accounted for 10 percent (USAID, 2015). Consequently, there may be a case for using residues from the agricultural sector as feedstock for energy generation.

Egypt is a large producer of oil and dry natural gas in Africa, but it is also the continent's leading oil and natural gas consumer (EIA, 2015). Oil products, natural gas and imported electricity account for more than 95 percent of domestic energy consumption (IEA, 2016a). Energy subsidies have been partly responsible for the country's high budget deficit, and, in the fiscal year 2013–2014, they accounted for 22 percent of total government expenditures (EIA, 2015; IMF, 2014). In response, the Egyptian government introduced an energy subsidy reform to reduce current subsidy levels (Ministry of Finance, 2015; James, 2015). Despite these subsidies, increases in consumption are attributed

12 This is the final list of feedstock for which the assessment was carried out. Initially a wider list was considered but was then narrowed down to a list of feasible feedstock based on energy content and selected bioenergy supply chains.

to various factors including swift economic and industrial growth, population growth, rising sales of private and commercial vehicles and energy subsidies. As a result of these trends and shortages in natural gas supply, crumbling infrastructure, and inadequate generation and transmission capacity, Egypt has experienced frequent electricity blackouts (EIA, 2015).

The Egyptian Ministry of Planning also intends to become a pioneer in renewable energy by maximising the use of domestic traditional and renewable energy sources (Ministry of Planning, 2016). Egypt aims to increase the installed capacity of renewable energy from a baseline of 3 385 MW in 2012 to 11 320 MW by 2020, corresponding to 20 percent of its power generation (RCREEE, 2013). The planned renewable energy mix is envisaged to include wind (12 percent), hydro (6 percent) and solar (2 percent) (Ministry of Electricity and Renewable Energy, 2013; EIA, 2015). No specific plan or target is set for bioenergy. More than 75 percent of Egyptian households rely on cylinders filled with LPG for cooking, which are perceived as costly even with a 95 percent subsidy. Given this context, briquettes and pellets produced from crop residues are analysed in this assessment together with their potential for meeting demand for cooking energy in Egypt.

Biomass assessment results[13]

Crop residues

The selection of which crop residues to analyse was based on the scale of production of each crop, as well as the suitability of the residue as feedstock for the selected bioenergy technologies (briquettes, pellets, and CHP from direct combustion or from biogas). At the national level, the total residue produced by all the selected crops was estimated to be around 30 million tonnes per year. A large portion of these residues consists of cereals (67.6 percent), wheat straw (37.7 percent), maize stalk (16.6 percent) and rice straw (10.7 percent). Other major crop residues come from sugar crops, with sugar cane bagasse contributing around 11 percent of total national crop residue production, followed by sugar beet haulm with 4.2 percent of total residues. Apart from crops, fruit tree prunings contribute 12.3 percent to national residue production.

The actual amount of residues available for bioenergy production depends on their other uses. In order to estimate the availability of crop residues for bioenergy production, current use practices for each residue (e.g. feed, soil cover) were discussed with the Egyptian Agriculture Research Centre (ARC). As a result, the total quantity of residues available for bioenergy production is estimated to be around 5 million tonnes per year. Maize stalks, rice straw, sugar cane bagasse and cotton stalk are the country's top four residue types, each with availability of more than 0.5 million tonnes per year. These four types account for around 80 percent of the total availability potential in the country.

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13 The full steps of the analysis can be found in the BEFS Assessment for Egypt, available from: http://www.fao.org/3/a-i6684e.pdf.

At regional level, the highest availability of residues is found in the Middle Delta region, followed by the Upper and Middle Egypt regions, each having more than 0.8 million tonnes of residues per year available for bioenergy. The Behera, Sharkia, Dakahlia and Kafr-El Sheikh governorates (all in the Middle Delta region) have the largest aggregated availability of residues in Egypt, each with an availability of between 0.59–0.87 million tonnes of residues per year. Among the four most commonly found residues in Egypt, maize stalk, rice straw and cotton stalk are most available in the Middle Delta region, while sugar cane bagasse is most available in the Upper Egypt region.

In addition to these residues, prunings from the various types of fruit production are promising feedstocks for bioenergy production, given their physical characteristics and high calorific values. The total availability of prunings from citrus fruit, olive, grape and palm date production is estimated to be around 777 thousand tonnes per year. The Middle Delta region has the highest share of prunings, with 58 percent of total availability concentrated in the region. This region also has the highest availability of each pruning type with the exception of olives. Olive prunings are mostly concentrated in the coastal region, accounting for 55 percent of availability of the residue.

Livestock residues

Livestock residues consist of manure from cattle (cow and buffalo) and chicken (layers and broilers).[14] In terms of production, the analyses estimate that, at the national level, approximately 57 million tonnes of cattle manure and 6 million tonnes of chicken manure are produced each year.

At the regional level, the Middle Delta region has the highest cattle manure production of all regions, at 31 million tonnes per year, or 55 percent of total manure production in Egypt. Furthermore, the Upper Egypt region, which produces 13 million tonnes of cattle manure per year (23 percent) and the Middle Egypt region, which produces 10 million tonnes (19 percent), have the second and third highest production volumes. Cattle manure is often used as soil amendment and may have other uses depending on local practices.

Based on discussions with national experts on current uses and availability of manure, the total amount of manure available for bioenergy use is estimated to be around 14 million tonnes per year.[15] Cattle manure for bioenergy purposes is most available in the Middle Delta region, at 7.8 million tonnes per year, accounting for approximately one-half of overall availability. At the governorate level, Behra and Sharkia have the largest availability of cattle manure for bioenergy, at 2.1 million tonnes and 1.4 million tonnes available annually,

14 Sheep and goat manure are not suitable since they cannot be collected, although collection may be feasible at a very small scale, which is beyond the scope of this assessment.

15 Full details on the available amounts and calculations can be found in the country report BEFS Assessment for Egypt, available from: http://www.fao.org/3/a-i6684e.pdf.

respectively. Together, these two governorates constitute 25 percent of total cattle manure availability in Egypt. In addition, out of 27 governorates, 12 show availability of between 0.5 and 1 million tonnes of manure, while 12 others have fewer than 0.5 million tonnes of manure available per year.

Accessibility of livestock residues depends largely on rearing practices, farm size, infrastructure (manure management systems), etc. As the analysis focuses on CHP from biogas, biomass availability for industrial-level biogas production has to be estimated considering large-scale farms because only they have the sufficient size to supply the industry. Therefore only farms with more than 50 heads were targeted. In light of this, data on cattle farm sizes per governorate were collected. The final availability estimate is 6 million tonnes per year. The analysis shows that the highest shares of larger farms (50 heads and over) are found in Behera, Sharkia, Fayoum, Qalyoubia and Suhag.

For chicken manure, the analysis is divided into broilers and layers, due to differences in the physical and chemical properties of their manure. The vast majority of broiler farms are located in the Behera governorate (57 percent of total broiler farms), while layer farms are mostly found in Sharkia, Qalyoubia and Gharbia (70 percent of total layer farms). Approximately 6.3 million tonnes of chicken manure are produced each year, of which broiler manure accounts for some 96 percent. The top two governorates with the highest production of broiler manure are Sharkia and Minya, together contributing 35 percent to total broiler manure production.

The governorate of Sharkia has the largest share of layer manure production, accounting for 24 percent of total output. As in the case of cattle manure, technical consultations were conducted with national experts to understand chicken manure management and use practices. These revealed that only between 0–5 percent of chicken manure might be available for new bioenergy projects. Considering this low level of availability and the uncertainty in this small share, this analysis does not consider chicken manure for bioenergy production. It might be possible to find pockets of availability of chicken manure, but estimates were not possible at this level of analysis.

In conclusion, as a result of the crop residue assessment, maize stalks, rice straw, sugar cane bagasse and cotton stalk, prunings from certain fruit trees, and cattle manure have been identified as biomass sources that could potentially be used to produce bioenergy in Egypt. The Middle Delta region appears to be the most promising area as far as total availability of residues is concerned. At the governorate level, Behra, Sharkiya, Dakahlia and Kafr-El Sheikh appear to be the most suitable locations to pilot a bioenergy project, given the availability of both crop and livestock residues there.

Energy end-use options assessment

Considering the types of feedstock selected and the Egyptian energy context, the energy end-use options analysed include industrial-level energy generation and energy carrier options for cooking at the household level. As a result, the extent to which bioenergy options could help meet the renewable electricity targets set by Egypt, or could be used to supply biomass as an alternative to LPG, were quantified.

Building on the estimated amounts of crop and livestock residues, the total available biomass was used to estimate (i) the total maximum electricity potential, and (ii) the total maximum amount of LPG that could be substituted.

Combined heat and power (anaerobic digestion or direct combustion)

Biomass-based CHP production was assessed as a source of electricity and compared to the renewable electricity targets in Egypt. The economic viability and sustainability of a CHP plant depends on various factors, including levels of availability and accessibility of residues, technology used and the scale of production.[16] Although all these variables are considered in this analysis, the most critical factor is the selling price. Three scenarios are considered: The first price (Scenario 1) is USD 0.05 per kWh, which represents the weighted average price of electricity for the period 2016–2017 as calculated by the Ministry of Energy (Egypt ERA, 2016). The second price (Scenario 2) is USD 0.10 per kWh, which is the current feed-in tariff (FiT) price.[17] The third comparison price (Scenario 3) is USD 0.15 per kWh, which considers an FiT that is 50 percent higher than the current one. The results of the assessment show that CHP schemes would start to be economically viable from a selling price of USD 0.10 per kWh, or Scenario 2.

In addition to the selling price, another way to improve the economic viability of a bioenergy plant is to minimise the cost of the residue. The results indicate

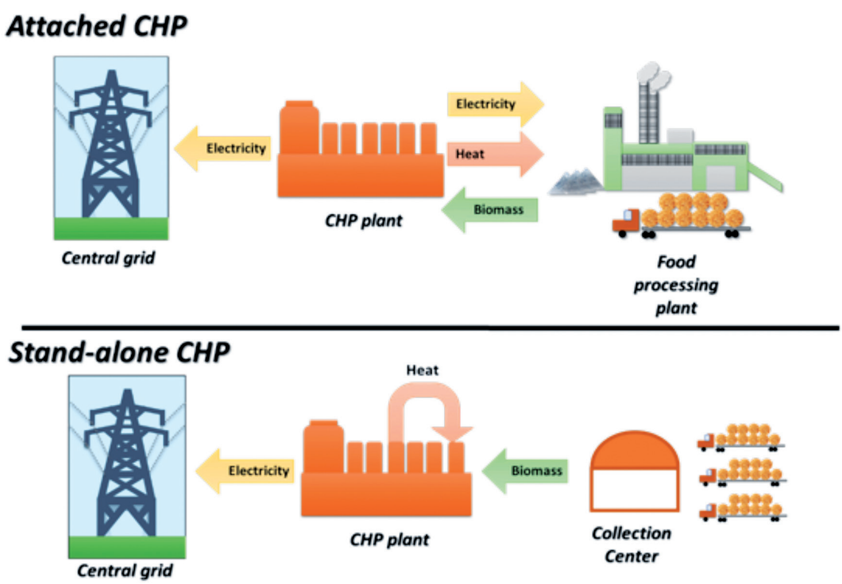
16 Two possible set-ups for CHP plants based on biomass residues were considered: the first is the "attached" layout. Here it is assumed that CHP plants are locally supplied with residues obtained from a single processing facility, and the heat and electricity generated is used chiefly by the same facility. Any energy surplus (typically electricity) is sold to the central grid. This option is preferred by industries such as sugar mills, paper plants and vegetable oil industries. The second is the "stand-alone" layout. In this option, CHP plants are built independently from processing facilities and can collect residues transported from different sources/areas. The heat and electricity generated is sold to the central grid or nearby consumers. This option is preferred by large-scale biogas plants. In the particular case of Turkey and Egypt, due to the lack of district heating networks in the first case and lack of interest for heat at household level in the second case, it was assumed that all energy (electricity and heat) produced by stand-alone plants is converted into electricity.

17 The average price of electricity was calculated for the period based on data from the Egyptian Electric Utility and Consumer Protection Regulatory Agency (Egypt ERA, 2016). The FiT was considered to be USD 0.10 per kWh based on the information available at the time of the analysis. This is in line with the FiT proposed by the Council of Ministers for Egypt in decision number 5/10/15/4 dated 28 October 2015, where it is stated that the FiT will be EGP 0.92 per kWh (Council of Ministers for Egypt, 2015), as reported by NREA.

that under a direct combustion scheme, the maximum payable price would range from USD 41–61 per tonne under the current FiT scenario (scenario 2), depending on the energy potential of feedstock and electricity generation capacities of CHP plants. This result illustrates the importance of the energy potential of feedstock and the scale economies in the viability of bioenergy projects: At their projected break-even point, large-scale CHP units fired with high energy potential feedstock will be able to pay higher prices (USD 61 per tonne) compared to smaller units using low energy potential feedstock (USD 41 per tonne). Hence plants relying on higher energy potential feedstocks are more resilient to fluctuations in feedstock market prices.

CHP plants developed close to or attached to agro-processing facilities would allow the use of freely available feedstock and minimise collection and transport costs. Such a scheme would enable the CHP plants to supply heat and electricity to the agro-processing plant. Any surplus electricity could then be sold to the central grid.

Figure 1: Comparison of attached and stand-alone CHP setups

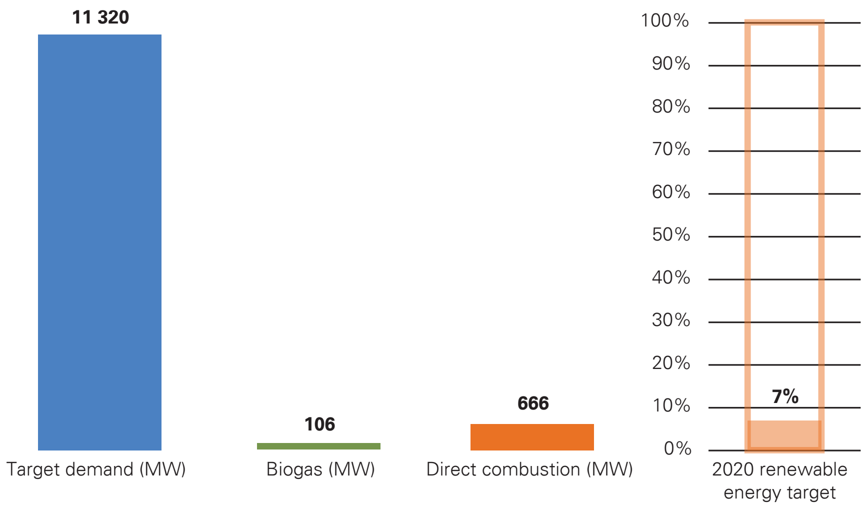


Source: Authors.

Under this set of profitable production conditions, the feedstocks that meet the technical requirements for direct combustion in CHP plants include maize stalk, rice straw, citrus prunings, olive prunings, palm date prunings, cotton stalk, grape prunings and sugar cane bagasse.

For biogas-based CHP plants, the limited availability of manure tends to both constrain the supply and force biogas producers to collect feedstock from different sites, increasing feedstock costs and reducing the profitability of biogas-based CHP plants to the extent that those based on manure alone are not feasible at industrial level (250–50 000 kW) under current FiT prices. However, biogas-based CHP plants at community level (not covered in this study) or those that use a combination of manure and crop residues could be profitable depending on the type of feedstock combination used and their collection source. Thus, among the available feedstock options, the most suitable combination would be a mix of cattle manure, sunflower stalk and sugar beet haulm. In this case, the maximum payable feedstock price that these plants might accept ranges from USD 1.8–32.3 per tonne for production scales varying from 250–50 000 kWh.

Figure 2: Comparison of CHP electricity generation capacities with 2020 renewable energy target in Egypt



Source: Authors.

Assuming that all the available biomass is accessible, that logistics are in place and that all the biomass available is dedicated to electricity generation with CHP technologies (666 MW from direct combustion and 106 MW from biogas), it would be possible to reach a maximum potential of 772 MW as the combined generation capacity of all governorates. This potential could: (i) cover 7 percent of the 11 320 MW renewable energy target; (ii) supply more than 2.2 million households; and (iii) avoid 2.9 million tCO_2 eq/year.

Figure 3 summarises the electricity generation capacity of CHP plants based on biogas and direct combustion from potentially available biomass residues.[18] The governorates of Sharkia, Dakahlia, Behera, Kafr El Sheikh, Menia and Qena are the most promising areas to establish the largest profitable plants. Overall, higher generation capacities are generally found around the Nile River areas, where the country is more industrialised. The feedstocks with the highest potential for energy generation in Egypt are rice straw in the north, maize stalk in the middle and sugar cane bagasse in the south, all through direct combustion.

Briquettes and pellets

The second energy end-use option considered in this study is to use the available agricultural residues to supplement some of the cooking energy demand by replacing LPG. In terms of briquettes and pellets, the economic profitability depends on the market price that producers receive. In this sense, the comparison price is the equivalent price of LPG (the subsidised LPG price), USD 4.3 per GJ.[19]

In the case of briquettes, the results of the analysis show that the maximum payable price can be up to USD 62 per tonne, while pellets could reach USD 93 per tonne. The variability in the production cost of briquettes and pellets is closely related to the spectrum of feedstock energy potential and the plant size. These results show that briquettes are better suited to small-scale production, both manual and mechanised. For large-scale mechanised production, pellets would be a more interesting option to add value to the residues, as observed in the maximum payable feedstock prices.

Overall, briquettes require a lower capital investment but are slightly less efficient than pellet technologies. The latter require a higher initial investment, but due to their greater efficiency are able to reduce operation costs and be more cost-effective at larger-scale levels of production. The most promising feedstocks for briquette and pellet production are prunings from citrus fruits including oranges, olives, palm dates and grapes, as well as cotton stalk, sugar cane bagasse, sunflower stalk, maize stalk and rice straw.

Based on these results, an effective way to use agricultural residues for briquette and pellet production would involve prioritising briquette technologies for small-scale operations, and pellets for large-scale operations. Again, assuming that all the available biomass were accessible and that logistics

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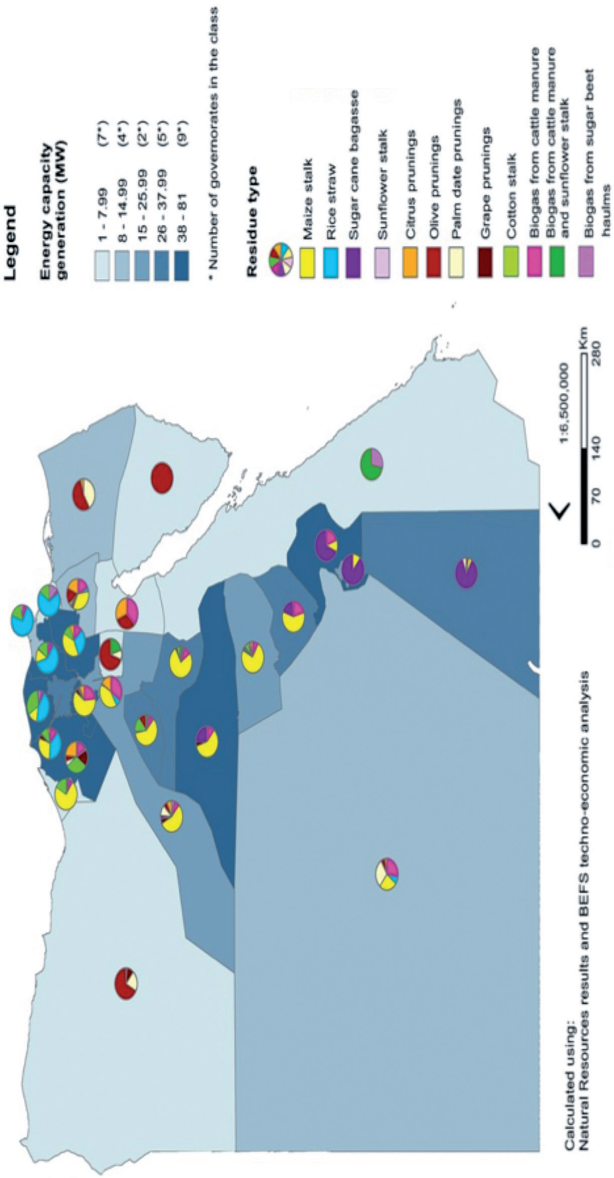
18 Full details on methodology, calculations, profitability conditions and generation capacities can be found in the country report BEFS Assessment for Egypt, available from: http://www.fao.org/3/a-i6684e.pdf.

19 Please note that all prices were collected in the country by the New and Renewable Energy Authority (NREA) (2016) and then converted to energy equivalent units (GJ) to simplify their comparison. Current prices in their original units are: briquettes (USD 175 per tonne), pellets (USD 119 per tonne) and LPG (USD 0.997 per cylinder).

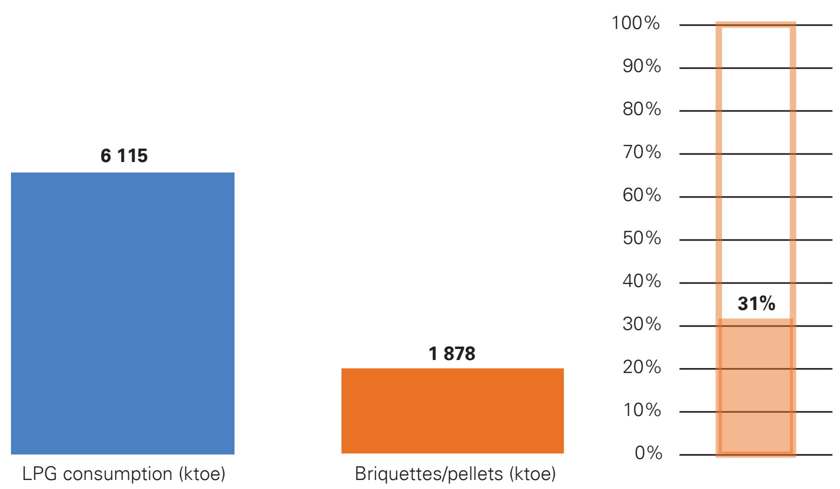
Figure 3: Potential electricity generation capacity and available residues for anaerobic digestion (biogas) and direct combustion CHP technologies



Source: Authors.

were in place, if all these crop residues were converted to briquettes/pellets, it would be possible to achieve a combined potential energy output of 1 878 thousand tonnes oil equivalent (ktoe) per year. When comparing this potential to the LPG consumption figures reported by the U.S. Energy Information Administration (EIA) (2010–2012) of 6 115 ktoe/year (EIA, 2016), it may be possible to replace 31 percent of LPG consumption by briquettes and pellets, supplying more than 1.6 million households and avoiding 3.6 million tCO_2eq/year (Figure 4).

Figure 4: Potential contribution of briquettes and pellets to replace LPG consumption

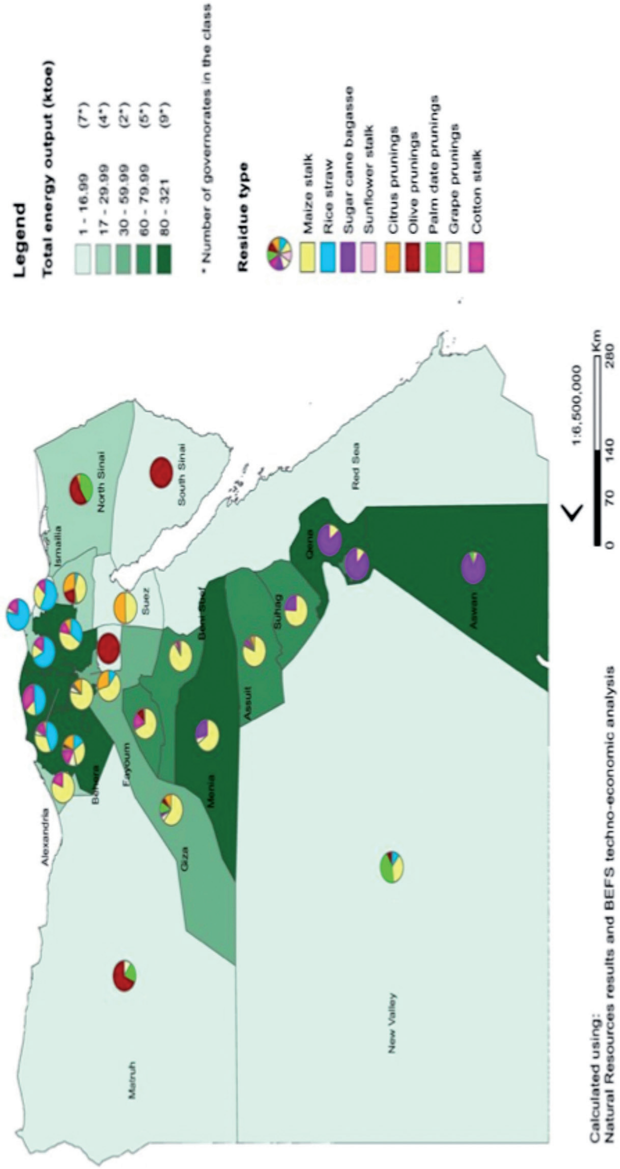


Source: Authors.

Figure 5 summarises the potential for energy generation using crop residues for briquettes/pellets that generate electricity. The governorates of Sharkia, Dakahlia, Behera, Kafr El Sheikh, Menia and Qena are the most promising areas where it may be possible to reach the greatest potential for substitution.

The results show that using agricultural residues for electricity or to replace cooking fuel can result in promising cost-effective options to increase energy access, reduce fossil fuel dependence and GHG emissions, and contribute to renewable energy targets. The feedstock options considered by the assessment are the same for CHP, briquettes and pellets. The ultimate decision on which bioenergy pathway should be prioritised at governorate level will depend on the local availability and accessibility of residues, as well as specific energy needs in each governorate.

Figure 5: Potential energy output and available residues for briquette/pellet technologies



Source: Authors.

Conclusions

The analysis indicates that Egypt has the potential to produce bioenergy from crop residues such as maize stalks, rice straw, sugar cane bagasse, cotton stalk, prunings and cattle manure. The Middle Delta region appears to be most promising as far as total availability of residues is concerned. At the governorate level, Behra, Sharkiya, Dakahlia and Kafr-El Sheikh are the most suitable locations to pilot a bioenergy project, due to substantial availability of both crop and livestock residues. However, it is important to reiterate that the potential to produce bioenergy depends largely on the actual availability and accessibility of residues, as well as on their geographical distribution. Five possible bioenergy pathways and related knowledge gaps are summarised below.

Combined heat and power (anaerobic digestion or direct combustion)

CHP using rice straw in plants attached to rice mills: The CHP plant would benefit from a continuous supply of rice straw; and the rice mills could become a potential buyer for the heat and electricity produced. From a biomass availability point of view, the optimal location for this first trial would be in the Dakahlia or Kafr-El Sheikh governorates. A more detailed verification of rice straw availability should be performed that considers other potential uses such as animal feed.

CHP using maize stalk: In the central part of the country there is good availability of maize stalks, particularly in the Menia and Sharkia governorates. However, the high collection cost of this feedstock has a negative impact on profitability of CHP plants. It would therefore be necessary to conduct a field analysis in the specific governorates to help estimate the detailed collection costs and gain an understanding of the possibility of using this residue in CHP plants attached to maize mill industries.

CHP from sugar cane bagasse: Energy production using sugarcane bagasse is a well-known technology applied in sugar mills. This feedstock is a very promising option, given its good availability and the absence of collection costs. A field analysis in the Upper Egypt region is needed to understand why sugar mill industries are not currently using this residue. Results of the assessment would provide a first indication that this option would be beneficial for sugar mills, allowing them to profit from the energy potential of this residue type. The two potential governorates would be Qena and Aswan.

CHP from cattle manure: Cattle manure is still an attractive option for biogas-based CHP. Additionally, under co-digestion,[20] this residue can be used for biogas production together with other available crop residues, but in smaller amounts. Using cattle manure would increase biogas generation capacities in

20 This term generally refers to the anaerobic digestion of multiple biodegradable substrates (feedstocks) in an anaerobic digestion system.

the country. Locating CHP plants attached to food processing industries may not be the most cost-effective option, since residue collection may need to be conducted from multiple sources. As a result, the location of these plants would depend mostly on the availability of biomass supply. Consequently, biogas to CHP producers would not necessarily have an industry outlet to which they could sell the heat produced. Alternatives for using the surplus heat produced would therefore need to be found in order to ensure economic viability. A field-level analysis would be required to define the most cost-effective option to use this heat, either as cooling or for the generation of additional electricity, depending on specific local energy needs. Potential governorates would be Behera, Menoufia and Beni Suef.

Briquettes and pellets

Briquettes and pellets from prunings: Briquettes and pellets are the most flexible option because they can use different feedstock types and operate at various plant size levels. Given the size restrictions highlighted in the report, briquette and pellet production may represent an attractive option to promote cost-effective LPG replacement and create self-supply energy solutions. The most favourable governorate for an in-field small-scale briquette project could be Behera, Ismailia or North Sinai, using olive, citrus and palm date prunings.

Turkey assessment

Scope of the assessment

Turkey has a large agricultural sector and is heavily dependent on imported fossil fuel to meet its energy demand. There is a growing interest to reduce fuel imports and achieve energy security by increasing the share of domestically-produced renewable energy in its energy mix. Considering the country’s goals, the analysis focuses on the use of available crop and livestock residues for the production of briquettes, pellets, and CHP from direct combustion or from biogas. The analysis is based on country-specific data and conditions, and was carried out at province level. The crop and livestock residues selected by the country for the analysis are reported in Table 2.

Table 2: Crop and livestock residue types selected in collaboration with Turkish stakeholders for the analysis

Residue	Crop or livestock from which the residue is generated
Straw	Rice
Cob	Maize
Husk	Maize, rice, hazelnut, soybean, groundnut
Stalk	Maize, cotton, sunflower, soybean, tobacco
Head	Sunflower
Shell	Almond, pistachio, hazelnut
Manure	Cattle and chicken

Source: Authors.

Note: The crop residues include residues spread in the field, collected in the field, and collected in the processing facility. Livestock residues include manure from cattle and chicken manure.

Country context

Turkey has a large agricultural sector and was ranked eighth in the world in terms of total gross agricultural production value in 2013[21] (FAOSTAT, 2016). The sector also accounted for about 25 percent of total employment in 2009 (OECD, 2011). Nevertheless, the share of agriculture in its GDP has been declining, falling from 10.8 percent in 2005 to 8 percent in 2014 (World Development Indicators, 2016). In 2010, agriculture accounted for 10.4 percent of exports and 5.3 percent of imports (OECD, 2012). Turkey's primary trading partners are the European Union, the United States, the Middle East and the Russian Federation. Agricultural exports are highly diversified with hazelnuts, wheat flour, food preparations, nuts, pastries, raisins, chocolate, tomatoes, chicken meat and tobacco making up the top ten exported agricultural products (based on value).

Total GHG emissions in Turkey[22] have more than doubled between 1990 and 2014. The energy sector is the largest driver of this increase, with its share of emissions increasing from 64 percent of the total in 1990 to 73 percent in 2014. Emissions from agricultural sector increased by 20 percent between 1990 and 2014 (National Inventory Submissions, 2015).

Turkey relies heavily on fossil fuels to meet its domestic energy demand. In 2012, the total primary energy supply comprised mainly fossil fuels (around 90 percent), with natural gas accounting for 32 percent, coal for 30 percent

21 At 2004–06 constant prices.

22 Excluding land use, land-use change and forestry.

and oil for 27 percent (IISD, 2015). Coal and natural gas have seen a significant increase in consumption over the past 2 decades, and they are both heavily imported: In 2015, Turkey imported around 96 percent of its total hard coal supply while almost 100 percent of oil and natural gas was imported due to limited domestic availability (IEA, 2016).

Turkey has observed strong economic growth over the last decades, resulting in a higher demand for energy from both industry and households. Consequently, the power-generation mix in Turkey has evolved and increasingly relies on imported natural gas. As a result, Turkey's electricity deficit[23] reached 6 percent of GDP in 2014 and oil and natural gas accounted for more than 90 percent of that deficit (IEEFA, 2016).

The government has developed a two-pronged approach to face the challenge of providing cheap power while maintaining energy independence in Turkey: (i) expansion of coal-fired power generation using domestic resources, and (ii) expansion of the role of renewable energy by producing 20 percent of all energy with renewable sources, including a sector target of producing 30 percent of its electricity from renewable sources. Within the electricity target, a further mandate to produce 1 000 MW from biomass alone is also envisaged.

Biomass assessment results[24]

Crop residues

Based on the residue types identified, the biomass assessment estimates the amount of residues produced and potentially available for bioenergy production, as well as their geographical distribution within Turkey on a province level.

In terms of collected residues, the analysis shows that the most available crop residues are sunflower head, maize cob, maize husk, rice husk and hazelnut husk. The availability of each of these exceeds 100 000 tonnes per year in Turkey. Of these residues, sunflower head has the highest availability, at 1 million tonnes per year. The Edirne (Marmara), Adana (Mediterranean), Tekirdag (Marmara), Konya (Central Anatolia) and Kirklareli (Marmara) provinces have the largest amount of collected residues in Turkey with sunflower head and maize cob taking the largest shares of the total. In terms of residues spread in the field, the most available residues are cotton stalk, maize stalk and sunflower stalk. The availability of each of these residues exceeds 1.8 million tonnes per year in Turkey, with cotton stalk showing the highest availability at 12 million tonnes per year. The Sanliurfa (Southeast Anatolia), Adana (Mediterranean), Aydin (Aegean), Hatay (Mediterranean) and Diyarbakir

23 The proportion of imported fuel required to run its grid.

24 The full steps of the analysis can be found in BEFS Assessment for Turkey, available from: http://www.fao.org/3/a-i6480e.pdf.

(Southeast Anatolia) provinces have the largest amount of spread residues in Turkey, with cotton stalk and maize stalk having the largest shares of the total.

The western provinces of Turkey show larger potential availability of crop residues collected in the field or in processing plants than the eastern provinces. However, the total quantity of residues spread in the field is considerably larger than the collected residues in Turkey as a whole.

It has to be stressed that collecting and mobilising residues that are spread in the field can be expensive and challenging, requiring considerable logistics and coordination among farmers and processing plants. The results therefore are to be considered as an initial indication of residue availability for energy production. The actual accessible amount of these residues would have to be quantified to proceed with certainty.

Livestock residues

In the case of livestock residues, only *production* of manure was covered due to lack of data on availability or accessibility.

Cattle manure seems to be evenly distributed across provinces. However, regionally this is not the case: the East and Central Anatolia regions have the largest share, followed by the Aegean, Black Sea and Marmara regions. The Konya (Central Anatolia), Balikesir (Marmara), Erzurum (East Anatolia), Izmir (Aegean) and Kars (East Anatolia) provinces have the largest production of cow and buffalo manure, with each of them producing more than 4 million tonnes per year. The distribution of cattle by holding size was also taken into account based on the data from Turkey's Biomass Energy Potential Atlas (BEPA). The results indicate that the majority (66 percent) of livestock holdings in Turkey have fewer than 26 animals per farm. Seven provinces, namely Gaziantep (Southeast Anatolia), Ankara (Central Anatolia), Kirsehir (Central Anatolia), Bursa (Marmara), Kirikkale (Central Anatolia), Konya (Central Anatolia) and Kirklareli, (Marmara) were found to have over 30 percent of holdings with more than 50 animals. Gaziantep is the only province in which one-half of the farms have more than 50 animals per farm. This is important to consider as, generally, manure is easier to collect and mobilise within larger farms.

The highest production of chicken manure from both layers and broilers was found in Manisa (Aegean), Balikesir (Marmara), Bolu (Black Sea), Afyon (Aegean) and Sakarya (Marmara), with each province producing more than 600 000 tonnes of manure. Manisa has the most chicken manure, producing around 1 million tonnes each year. Disaggregating the chicken manure production into layers and broilers, it was found that poultry and broiler manure is produced in similar quantities in Turkey as a whole. Around 4.88 million tonnes of layer manure is produced in Turkey every year as compared to 4.92 million tonnes of broiler manure. Afyon (Aegean), Konya (Central Anatolia), Manisa (Aegean), Balikesir (Marmara), İzmir (Aegean) have the largest production of layer manure with each of them producing more than 240 thousand tonnes per year. The largest amount of broiler manure is produced in Bolu (Black Sea), Manisa (Aegean), Balıkesir (Marmara), Sakarya (Marmara), Izmir (Aegean) with each of them producing more than 340 thousand tonnes per year.

Energy end-use options assessment

The energy end-use options analysed in this section are briquettes; pellets that heat and cool applications at the household level; and large-scale CHP from direct combustion or biogas through anaerobic digestion useful for both industries or households. The analysis revealed the energy amounts at province level that could be generated if the available natural resources are effectively mobilised and the extent to which bioenergy could contribute to the renewable energy national targets.

Combined heat and power (anaerobic digestion or direct combustion)

Under the current Turkish environment (prices, capital investments, tariffs and incentives), a set of production conditions for a profitable CHP generation were identified. However, due to the lack of accurate information regarding district heating networks in Turkey, it was not possible to assess in detail the profitability from selling heat to consumers. Consequently, in this case it was decided to analyse a technical modification in CHP plants to convert the cogenerated heat available for external consumers into additional electricity. This has implications in terms of additional capital investments but also additional revenues. The analysis considers two distinct bioenergy pathways:

(i) direct combustion of crop residues in CHP plants

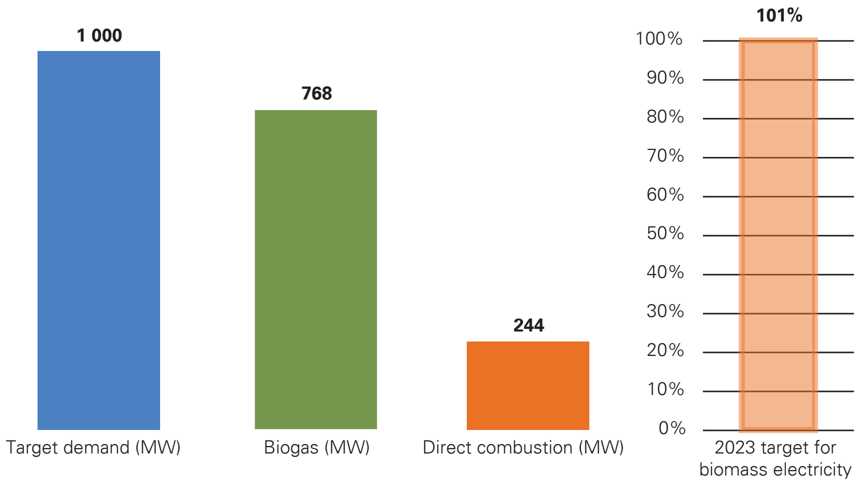
(ii) combustion of biogas produced from manure and selected crop residues in CHP plants

Given the current FiT plus premiums (USD 0.189 per kWh), both options can provide profitable operations under certain ranges of biomass energy potential and price. The maximum payable price for crop residues ranges from USD 53–123 per tonne depending on the energy potential of the feedstock and the CHP technology used. Among the set of profitable production conditions identified, the CHP plants need to operate using high efficiency technologies in order to be viable, prioritising the use of high energy potential feedstock. Moreover, only feedstock sourced at processing plants that have attached production schemes are considered (in order to minimise feedstock costs) and the electricity generated is assumed to be sold to the national grid (heat is used by the processing plant). Feedstock located in the field, on the other hand, should be used in stand-alone generation schemes, where it is more economically attractive to convert heat into electricity to then sell to the central grid. Under the above criteria and considering the feedstock deemed available for bioenergy production in the natural resource assessment, the most promising bioenergy supply chains are:[25]

- **For direct combustion to CHP:** groundnut husk, pistachio shell, hazelnut husk, rice husk; potentially maize cob and maize husk
- **For anaerobic digestion to CHP:** cattle manure, poultry manure and sunflower heads

The combined potential generation capacity using the above-mentioned residues and technologies can reach 1 GW (768 MW from biogas and 244 MW from direct combustion). This potential is around 101 percent of the 1 000 MW National Renewable Energy Action Plan (NREAP) target of energy to be produced from biomass by 2023.

Figure 6: Comparison of CHP electricity generation capacities with 2023 target for biomass electricity in Turkey

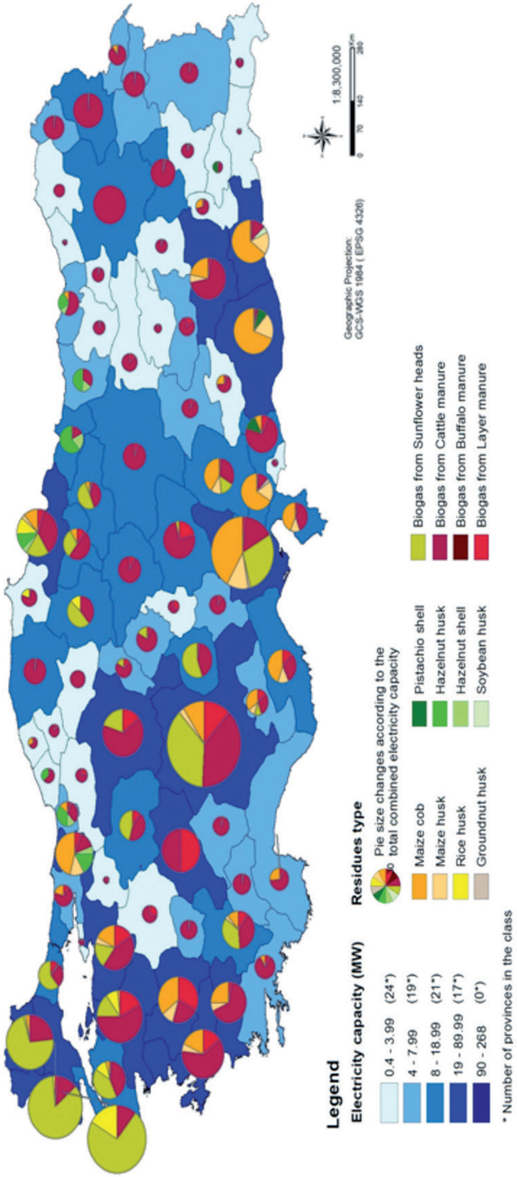


Source: Authors.

Figure 7 summarises how the 1 GW combined production capacity is distributed using the profitable combination of CHP systems (direct combustion and biogas) from selected biomass across Turkey. The western and southern parts of the country show the largest potential for electricity production.

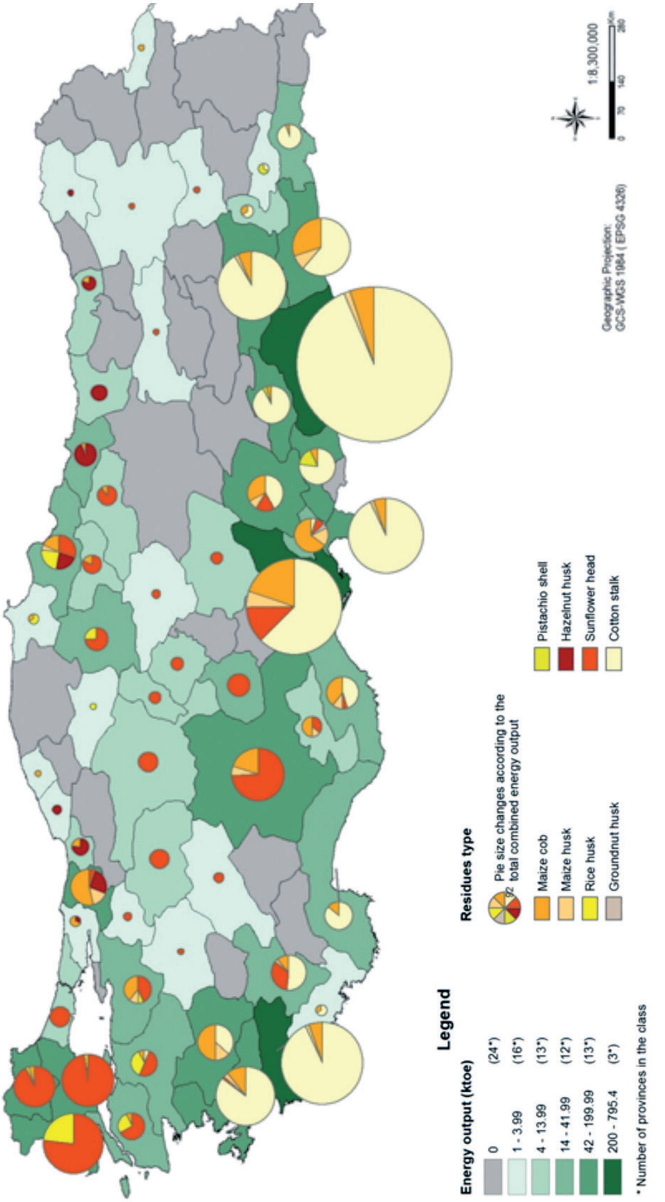
25 Full details on methodology, calculations, profitability conditions and results can be found in the country report BEFS Assessment for Turkey, available from: http://www.fao.org/3/a-i6480e.pdf.

Figure 7: Electricity capacity generation from crop residues (excluding cotton stalk) and livestock manure



Source: Authors.

Figure 8: Total potential energy output using briquette/pellet technologies



Source: Authors.

Briquettes and pellets

Briquette production is likely to be profitable at all plant sizes, while pellet production is likely to be even more profitable but only at medium and large-scale plant sizes. This means that pellets require larger investments with a higher return. Additionally, based on the current heating and cooking demand in Turkey, coal and fuelwood would be the most likely options to be replaced by biomass briquettes and pellets. Given this, it is important to take into account the energy potential and the maximum payable price for both briquettes and pellets after considering the region's coal and fuelwood consumption and how well-established these industries are. Based on these conditions, the BEFS assessment shows that the top ten most promising crop residues identified as potentially available and profitable are: hazelnut shell and husk, groundnut husk, cotton stalk, maize cob and husk, pistachio shell, soybean husk, sunflower heads and rice husk.[26]

The potential role of briquettes and pellets to meet Turkish renewable energy targets by 2023 was estimated on the basis of the biomass availability and profitable production capacities. Considering just those ten feedstock options, they were identified as promising. The total potential energy output for biomass converted to briquettes or pellets in Turkey is estimated to be 2 939 ktoe (Figure 8). Consequently, it would be possible to cover a big portion of the 3 537 ktoe target in Turkey for heating and cooling.

Most of the energy production using these briquettes/pellets from biomass residues would be focused on the eastern and southern provinces of the country using sunflower heads, maize cobs and cotton stalks. This last feedstock shares 60 percent of total potential energy output.

The accessibility of residues[27] that are spread in the field can have a major impact on their final use. To see the effect of accessibility issues in the country, cotton stalk was further examined as an example. This residue is abundantly available in Turkey. In consultation with national experts, a minimum accessibility level of 20 percent and a maximum of 50 percent of biomass available per province were estimated. Given this, if 20 percent of cotton stalk were to be accessed, this would result in 1 033 ktoe of energy. Given that the Turkish NREAP biomass heating and cooling target from renewable energy is set at 3 537 ktoe, the 1 033 ktoe would be equivalent to almost 30 percent of the NREAP target. If collection and mobilisation of cotton stalk were improved compared to the status quo, an even larger share of the NREAP target could be reached.

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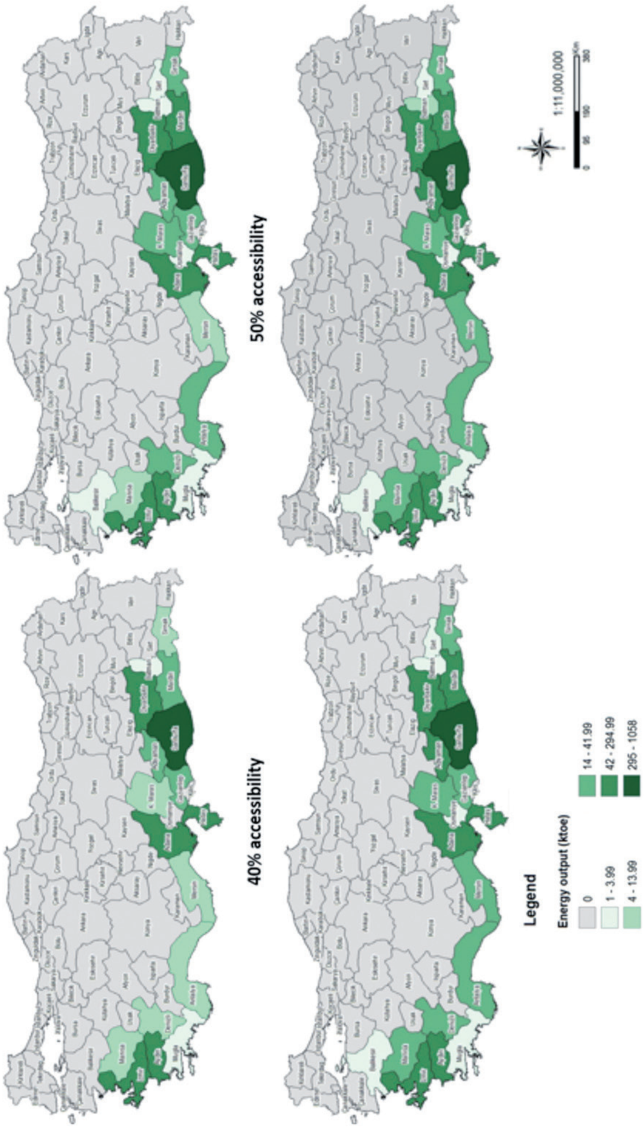
26 Full details on methodology, calculations, profitability conditions and results can be found in the country report BEFS Assessment for Turkey, available from: http://www.fao.org/3/a-i6480e.pdf.

27 Accessible residues are those that are available and can actually be mobilised for energy production. They are therefore a share of the available residues.

Figure 9: Total national potential energy output from cotton stalk at different accessibility levels



Source: Authors.

Figure 9 illustrates how the amount of energy generated through briquettes from cotton stalk increases when accessibility is improved. Cotton stalk production is mostly found in the southern provinces of the country, as shown by the maps in the figure. As accessibility improves, more energy can be produced for final consumption. Overall, the analysis shows that there is high potential for bioenergy production from cotton stalk, tied to the actual amount of residues that can be accessed.

Conclusions

The assessment illustrates that there is potential to generate energy from agricultural residues in Turkey, with the aim of reducing dependence on and substituting fossil fuels.

Combined heat and power (anaerobic digestion or direct combustion)

Attached CHP plants supplied with local residues obtained, for example, from a processing facility are better suited in more industrialised zones of the country with steam and electricity demands, whereas stand-alone CHP plants (either on-grid or off-grid) selling heat to nearby communities are more suitable in provinces with existing district heating networks. Both options might be able to sell electricity to the central grid as a main source of income depending on the electricity generated and the current incentives in place.

The analysis shows that the current FiT is sufficient for profitability under certain energy potential and price conditions, both for feedstock burnt directly in CHP plants as well as for feedstock that must first be converted to biogas. In the first case, it was found that feedstock burnt directly in CHP plants should have an energy potential larger than 13 MJ/kg with a maximum payable price of USD 50 per tonne. This maximum payable price might be increased to USD 68.5 per tonne in the case that all electricity production premiums granted by the government are accessed, and a FiT tariff of 0.189 USD/kWh could be reached. On the other hand, for feedstock converted to biogas first, the maximum payable range is between USD 35–70 per tonne.

Feedstock types that fulfil the technical conditions and are identified as available for bioenergy production in the Sustainable Biomass Assessment are: groundnut husk, pistachio shell, hazelnut husk, rice husk and potentially maize cob and maize husk (direct combustion) along with cattle manure, poultry manure and sunflower heads (anaerobic digestion). Using these identified feedstocks across different provinces in the country, it would be possible to reach a combined production capacity of around 1 GW. This production is comparable to the 1 GW target for energy production from biomass by 2023 set by Turkey.

Briquettes and pellets

According to the BEFS assessment, briquetting and pelletising biomass are promising options to support the achievement of the renewable energy production targets of the country. The analysis identifies that hot press technologies (no chemical binder, high electricity consumption) should be preferred for medium- and large-scale production, while cold press technologies (chemical binder, no electricity consumption) should be used for small-scale manual operations.

The results also indicate that pellet production is more profitable at medium and large plant levels (i.e. larger than 400 kg/h), while briquette production is profitable at all plant sizes.

Briquetting and pelletising are viable biomass densification options that can use residues for bioenergy efficiently without the need for any chemical transformation. The densified biomass can be used as replacement for fossil fuels or for briquettes and pellets produced from coal or fuelwood. Based on the current heating and cooking demand in Turkey, coal and fuelwood are the most likely candidates for replacement. For regions where biomass briquettes would replace coal, a feedstock with an energy potential larger than 15 Mj/kg and a maximum payable price of USD 60 per tonne can be used. Conversely, in regions where biomass briquettes would replace fuelwood, the minimum required energy potential is 13 Mj/kg with a maximum payable price of USD 250 per tonne. Therefore, it is advisable to prioritise this solution in provinces with high fuelwood consumption or deforestation problems.

Biomass briquettes and pellets would be competing in provinces with already established industries (e.g. the Samsun province); the calorific value of feedstock used for these industries should be at least 17 Mj/kg. Additionally, the price ceiling for this feedstock would be no more than USD 75 per tonne (briquettes – all scales) and USD 150 per tonne (pellets – large-scale).

Based on the identified set of conditions, the top ten most promising crop residues that are potentially available and profitable are: hazelnut shell and husk, groundnut husk, cotton stalk, maize cob and husk, pistachio shell, soybean husk, sunflower heads and rice husk.

The accessibility issue for selected crop residues and the potential of these options to contribute to Turkey's renewable energy target was illustrated using the cotton stalk example. Considering the amount of cotton stalk that would be available for bioenergy, briquette or pellet industries could be established in more than 20 provinces located in the Aegean, Marmara, Mediterranean, and Southeast Anatolia regions. The combined energy output obtained from accessing 20 percent of the cotton stalk was identified as 1 033 ktoe. This would supply an important share of the Turkish renewable energy target.

Moreover, the potential energy output might reach 2 589 ktoe, if cotton stalk accessibility were increased to 50 percent.

Next steps

The analysis and review illustrate the potential to produce bioenergy from crop and livestock residues in the two countries. It is important to stress that the actual amount of residues that can be used for bioenergy production is dependent on their real accessibility, which in turn is location-specific. In order to quantify this, accessibility would need to be determined at the local level. Thus, these results are only an indication of where to focus these efforts further.

The next steps to develop a well-functioning biomass value chain (collection, storage and transportation, pre-treatment and energy processing) that would ensure a steady, long-term and reliable supply of biomass for bioenergy production are:

(i) target the most viable areas and specific bioenergy chains;

(ii) discuss viability of these supply chains with local stakeholders and validate the assumptions, especially in terms of biomass availability and costs, at the local level;

(iii) identify and assess local solutions to address the collection and storage aspects of biomass to ensure biomass mobilisation;

(iv) based on the points above, identify a set of pilot phase projects to test the feasibility of the selected bioenergy chains.

Chapter 3 – Part B: Review of bioenergy potential from agricultural residues in Ukraine

Scope of the review

The objective of this assessment is to review the current understanding of the production and potential for agricultural residues to be used for bioenergy in Ukraine. The review analyses and compares the scope, methodology and results provided by different studies assessing this potential. Three studies were selected as most relevant considering the context and scope of this review based on initial desk research of available assessments:

(i) Potential of biomass for energy in Ukraine, Scientific Engineering Centre (SEC) Biomass (2010), referred to in this report as SEC Biomass (2010)
(ii) Bioenergy & bio-based opportunities in Ukraine, Tebodin Ukraine CFI (2013), referred to in this report as Tebodin (2013)
(iii) Utilisation of production residues in the primary agriculture and food-processing sectors, SEC Biomass (2014), referred to in this report as SEC Biomass (2014)

This analysis identifies the extent to which agricultural residue could potentially contribute to Ukraine's bioenergy targets within its national energy matrix.

Country context

Ukraine has an area of 603 500 km^2. The vast majority of the country consists of grassy, fertile plains (steppes) and plateaus, with mountains found only in the west (the Carpathians). The total population was just under 45 million in 2015, with 69 percent concentrated in urban areas and 31 percent in rural areas. The agricultural sector has traditionally been important for the economy. It boasts favourable natural conditions such as fertile black soil, amenable temperatures and precipitation that are conducive to the production of crops and livestock rearing. The country has significantly increased its agricultural productivity and exportable volumes of grains over the last decade, increasing the contribution of agriculture to GDP from 8.7 percent in 2006 to 14 percent in 2015.

Review of bioenergy potential

Crop residues

In terms of crop residues, the reviewed studies all include the four main crops of Ukraine: wheat, barley, maize and sunflower. For these crops, the SEC Biomass (2014) study carries out a more detailed analysis including husks and cobs in the case of maize residues and plant heads in the case of sunflower residues. Both the SEC Biomass (2010) and Tebodin (2013) studies evaluate only stalks as residues from maize and sunflower production. In addition to the four main crops, Tebodin (2013) analyses rapeseed straw and the SEC Biomass (2010) study analyses both rapeseed straw and straw from other cereals. Due to these differences in the number of residue types included in the assessments, comparing results for the corresponding energy potential was difficult (Table 3).

Table 3: Crop residues covered within reviewed studies

Crop	SEC Biomass (2010)	Tebodin (2013)	SEC Biomass (2014)
	Statistical data for 2008	Statistical data for 2011	Statistical data for 2013
Wheat	Straw	Straw	Straw
Barley	Straw	Straw	Straw
Maize	Stalks	Stalks	Stalks, husks and cobs
Sunflower	Stalks	Stalks	Stalks and heads
Rapeseed	Straw	Stalks	---
Other cereals	Straw	---	---

Source: Authors based on SEC Biomass (2010), Tebodin (2013) and SEC Biomass (2014).

In relation to the level of analysis, both the SEC Biomass (2010) and the SEC Biomass (2014) studies determined the technical potential of crop residues. Since what is called "technical potential" in SEC Biomass corresponds to "estimation of crop residue availability" in Tebodin, it is possible to compare the results provided for those values.

Where they analyse the same type of residues, the studies have different findings for availability potentials. This is in some cases significant, as with sunflower stalks for which the potential estimated by the Tebodin (2013) study is twice the potential estimated by the SEC Biomass (2014) study. Furthermore, although Tebodin (2013) and SEC Biomass (2014) report a relatively similar overall production and availability potential, the latter obtained this result with a larger range of residues analysed. More details about the potentials available for Ukraine are presented in Table 4. The overall result of SEC Biomass (2010) is also comparable with other studies available for Ukraine; however, again one should bear in mind the range of residue types analysed.

Table 4: Crop residues potential according to the three studies reviewed, million tonnes

Crop residues	SEC Biomass (2010)		Tebodin (2013)		SEC Biomass (2014)	
	Statistical data for 2008		Statistical data for 2011		Statistical data for 2013	
	Production and availability		Production and availability		Production and availability	
	Residues produced	Residues available	Residues produced	Residues available	Residues produced	Residues available
Wheat straw	Estimation for the whole group expressed in PJ only (Table 5).		32.0	6.4	28.4	8.5
Barley straw						
Maize stalks			34	17.7	30.3	12.1
Sunflower stalks			17.0	11.4	14.3	5.7
Rapeseed straw			2.9	2.0	---	---
Sunflower heads	---		---	---	6.6	2.6
Maize cobs	---		---	---	5.6	2.2
Leaves and shanks of maize ears	---		---	---	4.3	1.72
Total	**80***	**30***	**85.9**	**37.5**	**89.5**	**32.93**

*Approximate values calculated for the purpose of this review by using an average calorific value used in other studies.

Source: Authors based on SEC Biomass (2010), Tebodin (2013) and SEC Biomass (2014).

Table 5 shows the results for the residues available expressed in terms of energy potential. While both the SEC Biomass (2010) and the Tebodin (2013) studies already included results in terms of energy potential, the SEC Biomass (2014) study provided results in terms of tonnes of raw material both produced and available for each type of residue. Therefore, for the preparation of Table 5, the potentials from the SEC Biomass (2014) study were converted to energy units using the LHV specific to each type of residue.

Table 5: Energy potential of available crop residue by residue type according to the three studies reviewed, PJ

<table>
<tr><th>Residue type</th><th>SEC Biomass (2010)</th><th>Tebodin (2013)</th><th>SEC Biomass (2014)</th></tr>
<tr><td>Wheat straw</td><td rowspan="5">415</td><td rowspan="2">93</td><td rowspan="2">123</td></tr>
<tr><td>Barley straw</td></tr>
<tr><td>Maize stem/stalk</td><td>252</td><td>173</td></tr>
<tr><td>Sunflower stem</td><td>163</td><td>82</td></tr>
<tr><td>Rapeseed straw</td><td>28</td><td>-</td></tr>
<tr><td>Subtotal for comparable residues</td><td>415</td><td>535</td><td>378</td></tr>
<tr><td>Sunflower heads</td><td>-</td><td>-</td><td>37</td></tr>
<tr><td>Maize cob</td><td>-</td><td>-</td><td>31</td></tr>
<tr><td>Leaves and shanks of maize ears</td><td>-</td><td>-</td><td>24</td></tr>
<tr><td>Total</td><td>415</td><td>535</td><td>470</td></tr>
</table>

Source: Authors based on SEC Biomass (2010), Tebodin (2013) and SEC Biomass (2014).

In terms of energy potential, Tebodin (2013) estimates the highest potential of crop residues followed by SEC Biomass (2014) and SEC Biomass (2010). Even though SEC Biomass (2014) analyses a wider range of residue types, the estimated energy potential is lower than the one estimated by Tebodin (2013).

The studies differentiate between the unit of analysis for the geographical distribution of the residues. Tebodin (2013) shows the aggregated potential of all biomass types (including primary crops residues, livestock and secondary/processing residues) while SEC Biomass (2010) shows the aggregated potential for all primary residues. SEC Biomass (2014) presents the geographical distribution differentiated by crop: the spatial distribution is presented for barley and wheat straw separately, and aggregated for maize residues (stalks, husks, cob) and sunflower residues (heads and stalks). Hence, it is impossible to compare the studies' geographical aspects.

Livestock residues

All three studies analysed the same three livestock residues: cattle, pig and poultry manure. For residue potential, Tebodin (2013) and SEC Biomass (2014) only consider agricultural enterprises whereas SEC Biomass (2010) does not clearly state this information so one could assume that livestock from both households and enterprises are taken into account. Furthermore, SEC Biomass (2010) and SEC Biomass (2014) estimate the availability of animal manure while Tebodin (2013) estimates only the theoretical potential i.e. the estimated manure production based on the number of animal heads and types. However, it is important to note that the two SEC Biomass studies estimate availability differently: SEC Biomass (2010) uses the overall availability factor of about 75 percent without clarifying for which specific uses the remaining 25 percent is used. SEC Biomass (2014) on the other hand assumes that 100 percent of the volume of manure produced goes to the fields and therefore is not available for alternative purposes. As shown in Table 6, Tebodin (2013) and SEC Biomass (2014) find relatively similar results for pig manure production while there is a more significant difference between the estimates of chicken and cattle manure. Although Tebodin (2013) estimates a higher total production than SEC Biomass (2014), the latter estimates a higher total energy potential because of its findings for pig and chicken residue production, which have larger biogas yields.

Table 6: Results for livestock residues according to the three studies reviewed

Studies	SEC Biomass (2010)		Tebodin (2013)		SEC Biomass (2014)	
Estimate of:	Theoretical potential/ Residues produced	Energy potential (biogas)	Residues produced	Energy potential (biogas)	Residues produced	Energy potential (biogas)
Unit	Million tonnes of raw material	PJ	Million tonnes of raw material	PJ	Million tonnes of raw material	PJ
Cattle manure	-	90.9	20.5	15.1	14.5	10.7
Pig manure			4.7	3.8	6.1	4.9
Poultry residues			2.9	6.9	5.6	13.3
Total	-	**90.9**	**28.1**	**25.7**	**26.2**	**28.9**

Studies	SEC Biomass (2010)		Tebodin (2013)		SEC Biomass (2014)	
Estimate of:	Technical potential/ residues available	Energy Potential (biogas)	Residues available	Energy potential (biogas)	Residues available	Energy potential (biogas)
Unit	Million tonnes of raw material	PJ	Million tonnes of raw material	PJ	Million tonnes of raw material	PJ
Cattle manure						
Pig manure	-	68.1	Not estimated	Not estimated	Assumed 0	Assumed 0
Poultry residues						
Total	-	**68.1**	Not estimated	Not estimated	Assumed 0	Assumed 0

Source: Authors based on SEC Biomass (2010), Tebodin (2013) and SEC Biomass (2014).

All three studies map their residue potential estimates at the province level – but in different ways. Tebodin (2013) maps the livestock residue potential alongside all other biomass types analysed within that study. SEC Biomass (2010) provides maps specifically for livestock residue potential with the theoretical and technical potential expressed in energy units, but with no differentiation between manure types. Finally, SEC Biomass (2014) maps this potential (only *production* since *availability* is assumed zero) per manure category.

The above-mentioned comparison emphasises the importance of the methodological approach, especially the availability factor and possibly the lack of more detailed data. The differences between the Tebodin (2013) and SEC Biomass (2014) studies in terms of quantified energy production potentials are not significant but they do imply that animal manure is essentially unavailable for additional purposes beyond soil amendment, e.g. production of biogas for energy generation. However, these studies indicate expected growth in animal numbers and thus the possible availability of manure for purposes other than soil fertilisation in the future.

Food processing residues

The SEC Biomass (2014) study analyses the highest number of food processing residue types while SEC Biomass (2010) only assesses bagasse from sugar plants and sunflower and rice husks. Furthermore, although it seems that the range of residues analysed in Tebodin (2013) and SEC Biomass (2014) differ solely with respect to the meat and flour/cereal industries, a more detailed insight into the exact residue types reveals that the difference is much higher. Due to the differences in the number of residue types used for each study, comparing results is difficult and could be misleading (Table 7).

Table 7: Food processing residues covered within the studies reviewed

Studies	SEC Biomass (2010)	Tebodin (2013)	SEC Biomass (2014)
Rice production	Rice husks	---	---
Sugar plants	Bagasse	Sugar beet pulp (SBP)	SBP, molasses, defecation mud, tops
Oil extraction plants	Sunflower husks	Sunflower husks	Sunflower husks, extraction cake, soapstocks
Breweries	---	Brewers' spent grain (BSG)	BSG, spent hop, surplus yeast
Dairy industries	---	Milk whey, waste water	Whey, buttermilk
Distilleries	---	Grains	Stillage, surplus yeast
Meat production	---	---	Slaughterhouse residues
Flour and cereal industries	---	---	All types

Source: Authors based on SEC Biomass (2010), Tebodin (2013) and SEC Biomass (2014).

Table 8 presents the results of the studies reviewed in terms of food processing residues production. Differences in the results can already be observed in the production estimate, which could partly be due to different scope of residue types analysed (Table 8).

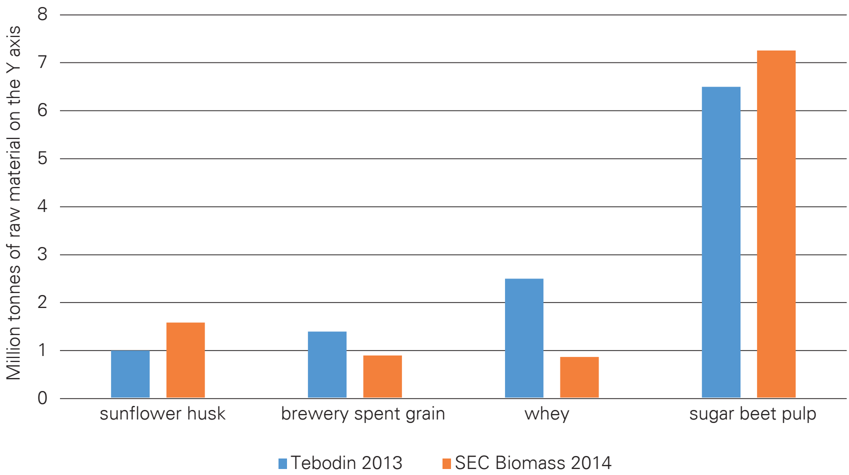
Table 8: Food processing residue potential according to the three studies reviewed, million tonnes

Residues from	SEC Biomass (2010)	Tebodin (2013)	SEC Biomass (2014)
Rice production	Expressed as a whole and in PJ only	---	---
Sugar plants		6.5	8.8
Oil extraction plants		1	4.7
Breweries	---	1.4	1.0
Dairy industries		3.4	1.0
Distilleries		4.5	2.1
Meat production		---	1.3
Flour and cereal industries		---	1.1
Total		15.6	19.9

Source: Authors based on SEC Biomass (2010), Tebodin (2013) and SEC Biomass (2014).

Furthermore, the Tebodin (2013) and SEC Biomass (2014) studies have four specific residue types in common: sunflower husk, BSG, SBP and whey. Figure 10 shows the extent to which these studies differ on production residue estimates. As can be observed in Table 8, the largest difference is between whey estimates.

Figure 10: Comparison of production of certain processing residues



Source: Authors based on Tebodin (2013) and SEC Biomass (2014).

It is important to note that availability has been addressed differently across the studies. In the case of SEC Biomass (2014), although the study concludes by sharing the options it considers most viable, available residue amounts are not fully quantified for each residue type. Nevertheless, even when the studies do estimate the availability for the same residue type, some differences can still be observed. For example, SEC Biomass (2010) does not estimate the availability of sunflower husks; Tebodin (2013) states that around 1 million tonnes are produced annually with 70 percent already utilised (pelletised for on-site use for energy and for export) and 30 percent is still left unused; and SEC Biomass (2014) assumes about 12 percent availability (corresponding to about 162 000 tonnes). This single example illustrates the complexity of the comparison. An accurate comparison would only be possible if all the details (i.e. the methodology used for the assessment and other details on the identified uses of residues) were explicitly given in the reports.

Finally, Tebodin (2013) shows the aggregated potential of all biomass types whereas SEC Biomass (2014) presents the spatial component for several residue types separately. Hence, further analyses and comparison could not be performed.

Conclusions

The comparison of the selected studies was performed based on how they approach the most important elements of biomass potential analyses (biomass types included, differentiation between production and availability, coverage of the geographical distribution, etc.) and the results of their assessments. However, it should be emphasised that the final outcome of such studies depends on many factors, such as the purpose of the assessment, availability of data and when the study was performed, all of which influence the applied methodology and thus the results. These factors should therefore be taken into consideration when drawing conclusions from this review.

Table 9 summarises the main results and elements of biomass potential assessments between the three reviewed studies. It is evident that the quantified potentials are difficult to compare. However, all three studies conclude that crop residues have the most significant potential of all agricultural residues. It is not completely clear whether livestock or processing residues would be the second most important source. Based on this, the national bioenergy targets set by the NREAP could be primarily achieved through the utilisation of crop residues.

Table 9: Summary of the main elements of the compared studies

Title of the studies		Potential of biomass for energy in Ukraine	Bioenergy & bio-based opportunities in Ukraine	Utilisation of production residues in the primary agriculture and food-processing sectors
Author and year of the study		SEC Biomass (2010)	Tebodin Ukraine CFI (2013)	SEC Biomass (2014)
In this report referred to as:		SEC Biomass (2010)	Tebodin (2013)	SEC Biomass (2014)
Data used in the study		Statistical data for 2008	Statistical data for 2011	Statistical data for 2013
Geographical distribution		Province level but with different details presented		
Production estimate		Yes		
Availability estimate		Yes but with certain fine differences		
Crop residues	Wheat	Straw	Straw	Straw
	Barley	Straw	Straw	Straw
	Maize	Straw	Straw	Stalks, husks and cobs
	Sunflower	Stalks	Stalks	Stalks and heads
	Rape	Straw	Straw	---
Livestock residues	Cattle manure	Yes, livestock in both enterprises and households included	Yes, only enterprises included	Yes, only enterprises included
	Pig manure			
	Poultry manure			
Food processing residues	Rice production	Rice husks	---	---
	Sugar plants	Bagasse	SBP	SBP, molasses, defecation mud, tops
	Oil extraction plants	Sunflower husks	Sunflower husks	Sunflower husks, extraction cake, soapstocks
	Breweries	---	BSG	BSG, spent hop, surplus yeast
	Dairy industries	---	Milk whey, waste water	Whey, buttermilk
	Distilleries	---	Grains	Stillage, surplus yeast
	Meat production	---	---	Slaughterhouse residues
	Flour and cereal industries	---	---	All types

Source: Authors based on SEC Biomass (2010), Tebodin (2013) and SEC Biomass (2014).

Table 10 summarises the estimated potentials for crop and livestock residues.

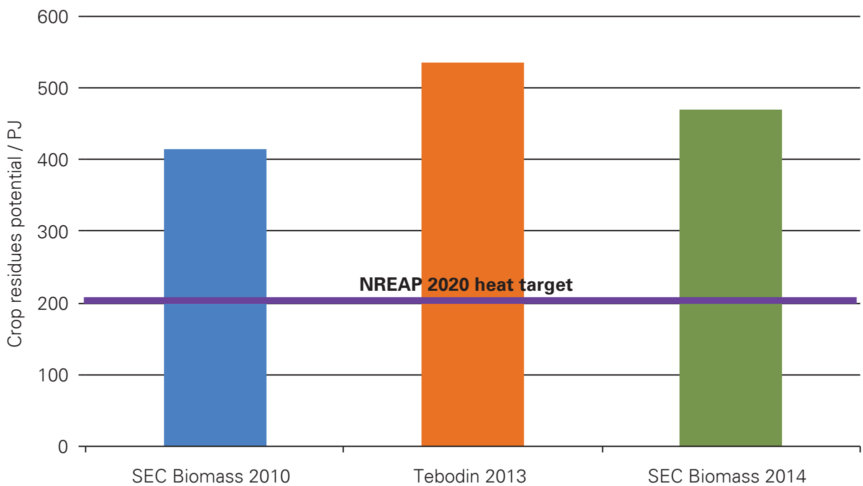
Table 10: Results of residue potentials from the studies reviewed

Residue group	SEC Biomass (2010)		Tebodin (2013)		SEC Biomass (2014)	
	Residues produced	Residues available	Residues produced	Residues available	Residues produced	Residues available
	PJ		PJ		PJ	
Crop residues	1 135.5	415.1	1 231.6	535.4	1 277.5	470
Livestock residues	90.9	68.1	25.7	Not estimated	28.9	Assumed 0

Source: Authors based on SEC Biomass (2010), Tebodin (2013) and SEC Biomass (2014).

Each of the reviewed studies estimates both production and availability of crop residues. With regard to energy production, crop residues could be used for various purposes, in CHP plants, plants producing only heat and also for the production of second generation biofuels. However, considering the fact that crop residues are solid biomass, which is usually used for heat production alone, within this report the estimated availability potentials are compared to NREAP heat targets (see Figure 11).

Figure 11: Comparison of the availability of crop residues with NREAP 2020 heat target



Source: Authors.

Figure 11 illustrates that the estimated availability of crop residues, regardless of the source, is significantly larger than the 2020 heat target from solid biomass. At an estimated 203 PJ of potential energy, crop residues could play an important role in meeting the NREAP target. It should be noted that sunflower husks as processing residues are not included in this potential, since they can also be used for direct combustion. However, the significance remains high.

With regard to livestock residues, only the SEC Biomass (2010) report estimates the availability (technical potential) while the Tebodin (2013) does not provide any estimate except production levels, and SEC Biomass (2014) estimates zero availability. Given this, one can conclude that the availability aspect of livestock residues is questionable and comparisons with the NREAP target cannot be considered reliable.

In relation to processing residues, these can be used in several different energy production pathways but the most common is currently biogas production. However, Tebodin (2013) estimates availability only for sunflower husks, which are better to use in direct combustion. SEC Biomass (2014) estimates a high availability share for sunflower extraction cake and SBP but it concludes that the viable feedstocks are SBP, whey and BSG. Again, only the SBP availability has been quantified (about 6 million tonnes of raw material in 2013). If this is used for biogas production, which is then used for electricity generation (low efficiency of 20 percent), SBP could contribute up to 68 percent of the NREAP 2020 electricity target from biogas.[28]

Based on this review, the key takeaway points are:

- Several assessments estimate the potential of agricultural residues in Ukraine. All reviewed studies analyse a different range of residue types, while only the livestock residue types are the same across all studies.
- Methodologies across the reviewed studies are comparable to a certain extent. All studies estimate residues production potential in similar ways while availability is not addressed in the same way, when it is addressed.
- The level of details presented within the studies is not the same; thus comparison and verification are difficult.
- Studies acknowledge that the estimated potentials could be utilised for different purposes, one of which is energy production. Tebodin (2013) and SEC Biomass (2014) even address the bio-based economy.

28 Percentage estimated assuming a biogas yield of 120 m^3 per tonne of SBP (wet state), with a calorific value of 21 MJ/m^3 for biogas and an efficiency in electricity production from biogas of 20 percent. The value for the biogas yield was obtained from Geletukha et al., The prospects of biogas production and use in Ukraine. Available from: http://www.uabio.org/img/files/docs/position-paper-uabio-4-en.pdf.

- The availability of livestock residues is not fully clarified and requires further research in order to confirm previous assumptions and estimates.
- Further research is also recommended regarding food processing residues and their availability for energy production.
- Geographical distribution of the different residue production potentials has been captured within the studies but in different ways. Overall, the potential is mostly located in the central part of Ukraine, while the lower potential is located in the western provinces.
- All studies say that higher volumes of residues could be expected in the future due to likely increases in production of the main products (crops, meat/milk/eggs, sugar, oil, etc.). Hence, even if some of these residues are currently already fully utilised, additional amounts might become available for new purposes in the future.
- The results indicate that overall Ukraine has significant potential in agricultural residues. Crop residues have the highest share in the overall potential estimated. Furthermore, utilisation of crop residues could significantly facilitate meeting the NREAP 2020 heat targets. However, the viability of this might be impacted by practical accessibility and local conditions.

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