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BEFS ASSESSMENT FOR TURKEY

Sustainable bioenergy options from crop and livestock residues

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ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

ENVIRONMENT CLIMATE CHANGE [ENERGY] MONITORING AND ASSESSMENT

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Sustainable bioenergy options from crop and livestock residues

Food and Agriculture Organization of the United Nations
Rome, 2016

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EXECUTIVE SUMMARY

The Context of the Report and Stakeholders

This report was developed under the collaborative agreement between European Bank for Reconstruction and Development (EBRD) and Food and Agriculture Organization of the United Nations (FAO), as part of the Sustainable Resource Initiative of the EBRD and building on the Bioenergy and Food Security (BEFS) Approach of FAO. The scope of the report is to assess the availability of agriculture residues for energy production covering pathways from agriculture residues to heat, power and combined heat and power. The results provide an overview of which bioenergy pathways can be viable and the locations of the bioenergy potential, given the overarching existing policy framework.

The Sustainable Resource Initiative falls under the new Green Economy Transition approach of the EBRD. The BEFS Approach is part of the Sustainable Bioenergy Support Package of FAO. The 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 transition economies to increase the use of renewable energy. Amongst the renewable energy options, agriculture residues to energy pathways are considered. With the support of the EBRD, the Turkish Ministry of Energy and Natural Resources has developed the first National Renewable Energy Action Plan in line with the EU's Renewable Energy Directive. The Shareholder Special Fund (SSF) is kindly acknowledged for the support on the work and overall assessment carried out under and within this report.

A core element of the support package of FAO is the BEFS Approach and the BEFS Sustainable Biomass Assessment. The assessment is to form the basis for the bioenergy policy development process by identifying which bioenergy options can be feasible within the country, based on the country context, conditions and energy and agricultural requirements.

The work was implemented in close collaboration with General directorate of agricultural research and policy (TAGEM) of the Ministry of Food, Agriculture and Livestock and Ministry of Energy and Natural Resources with support from the Ministry of Environment and Urbanization and the Ministry of Forestry and Water Affairs, with inputs from other national experts in the field of bioenergy.

Scope and Structure

Turkey has a large agriculture sector and has set a target to produce 30 percent of its electricity from renewable sources and to diversify from heavily imported fossil fuels. The scope of this report is to provide an initial assessment of the availability and the potential use of agricultural residues in Turkey for the production of heat, power or combined heat and power. The specific agriculture residues covered in detail are crop and livestock residues. The energy end use options considered are briquettes, pellets, and large-scale combined heat and power from direct combustion or from biogas.

To accomplish this assessment, the tools and methodology of the BEFS Approach, including the sustainable biomass assessment and the BEFS Rapid Appraisal tools, were utilised. The analysis was carried out at province level, uses country-specific data and conditions, and builds as much as possible on previous analyses carried out in Turkey and on ongoing efforts related to bioenergy potential assessment from agriculture residues.

In addition to this, assessment of the availability of agro-processing residues was carried out through a short questionnaire conducted among agro-food and wood processing facilities.

The report is structured in five parts and covers a country overview of the agriculture and energy sectors, the assessment of the biomass potential, a techno-economic assessment of the energy end use options, the assessment of the availability of agro-processing residues, and a set of conclusions and recommendations for next steps based on the outcome of the analysis.

Country Context

Turkey is the seventh largest agricultural producer in the world (OECD, 2011b). Given the size and diversity of agricultural production, a large amount of residues are likely generated from the agriculture sector. Given this, there might be potential to use the agricultural residues that are not utilised for other purposes as potential feedstock for energy generation, which is part of the scope of this report.

Turkey relies heavily on fossil fuels to meet its domestic energy demand. Fossil fuels make up approximately 89 percent of the total primary energy supply and are heavily imported. The country's principal objective is energy security, therefore the aim is to: diversify its energy supply routes and source countries; increase the share of renewables to the highest possible extent and include nuclear power into its energy mix; make steps towards improved energy efficiency; and contribute to Europe's energy security. The country also estimates that there will continue to be immense growth in energy demand and wants to meet this demand in a manner that is timely, adequate and affordable (Ministry of Foreign Affairs, 2011b; Ministry of Development, 2014).

Furthermore, Turkey has substantial potential to produce energy from renewable energy resources and the country aims to increase its use of geothermal, hydro, wind and solar energy resources as well as slowly commissioning nuclear power so as to reduce its dependency on imported fossil fuels (Ministry of Foreign Affairs, 2011b). Turkey's Renewable Energy Action Plan (REAP), which was created in alignment with 'the Renewable Energy Directive' of the European Parliament and of the Council, has set a target for renewable energy sources to contribute 20 percent of total general energy consumption by 2023 (Ministry of Energy and Natural Resources, 2014).

Biomass Assessment

The analysis identified the main types of residues available for bioenergy production as well as their geographical distribution within Turkey. Two main agricultural residue types were considered: crop residues (collected or spread) and livestock residues (cattle, buffalo and chicken manure).

Collected residues (those residues that are either collected in the field after harvest or at the processing plant after the processing and packaging of the final product) that show larger availability include sunflower head, maize cob, maize husk, rice husk and hazelnut husk and there are more than 100 000 tonnes of each available per year. Edirne (Marmara Region), Adana (Mediterranean Region), Tekirdağ (Marmara Region), Konya (Central Anatolia Region) and Kirklareli (Marmara Region) provinces have the largest amount of collected residues, with sunflower head and maize cob having the largest shares in the total.

Residues that are spread in the fields that show larger availability are cotton stalk, maize stalk and sunflower stalk with each exceeding 1.8 million tonnes available per year in Turkey. Sanliurfa (Southeast Anatolia Region), Adana (Mediterranean Region), Aydin (Aegean Region), Hatay (Mediterranean Region) and Diyarbakir (Southeast Anatolia Region) provinces have the largest amount of spread residues, with cotton stalk and maize stalk having the largest shares in the total.

In general, the western provinces show a larger availability potential of crop residues that are collected than the eastern provinces. However, the total quantity of residues that are spread in the field is considerably larger than the collected residues in Turkey as a whole. Nevertheless, collecting and mobilising residues spread in the field can be expensive and challenging.

Due to the lack of data on the current uses of livestock residues, the analysis only estimated the total residues produced at the province level in Turkey and not their availability. Cattle manure seems to be evenly distributed across provinces. However, overall the East and Central Anatolia regions have the largest share of manure in the country, followed by the Aegean, Black Sea and Marmara regions.

Konya (Central Anatolia Region), Balikesir (Marmara Region), Erzurum (East Anatolia Region), Izmir (Aegean Region) and Kars (East Anatolia Region) provinces have the largest production of cattle and buffalo manure, with each of them producing more than 4 million tonnes of manure per year. The highest amount of chicken (layer and broiler) residues were found in Manisa (Aegean Region), Balıkesir (Marmara Region), Bolu (Black Sea Region), Afyon (Aegean Region) and Sakarya (Marmara Region) and each province produces more than 600 000 tonnes of manure. Manisa has the most chicken manure, producing around 1 million tonnes each year.

The majority (66 percent) of livestock holdings in Turkey are relatively small holders, having less than 26 animals per farm, which is significant since small farms make it more difficult to collect and mobilise manure.

Techno-economic Assessment

The objective of the analysis for Turkey was to understand how the biomass potential identified in the Natural Resource Assessment for different provinces can be used to produce bioenergy in a way that is technically feasible as well as economically viable. In doing so, the assessment also examines the extent to which the use of agricultural residues to produce bioenergy can contribute to achieving the Turkish renewable energy targets. Agricultural residues can be used to produce electricity as well as heat and therefore the energy end use options analysed in the study are briquettes, pellets, and large-scale combined heat and power from direct combustion or from biogas through anaerobic digestion.

Under current Turkish settings (prices, capital investments, tariffs), a set of profitable production conditions for the cogeneration of heat and power (CHP) was defined. However, due to the lack of large heat distribution infrastructure, the actual price of heat was unobtainable so it was not possible to assess the profitability of combined heat and power production. Therefore, the only main product assessed of the CHP plants was electricity. It was found that the CHP plants need to operate using high efficiency technologies, preferably utilising high-energy potential feedstock. Aditionally feedstock located at processing plants should be used in attached production schemes and should sell electricity to the central grid (heat is transferred to the processing plant). Whereas feedstock located in the field should be used in stand-alone production schemes and the heat should be converted into electricity and sold to the central grid. The analysis considered two distinct bioenergy pathways :

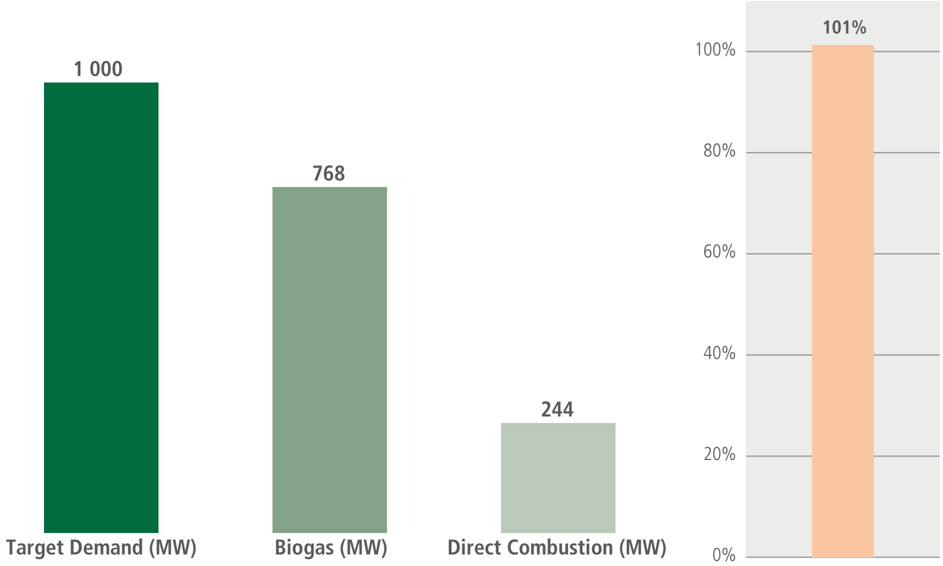
1. residues burnt directly in CHP plants (crop residues mainly), and;
2. residues that first need to be converted into biogas (manures mainly).

Given the current feed-in tariff, both options can provide profitable operations under certain ranges of biomass energy potential and price. Feedstock that were deemed available for bioenergy production in the natural resource assessment and that that met these criteria were :

1. For direct residue combustion :groundnut husk, pistachio shell, hazelnut husk, rice husk and *potentially* from maize cob and maize husk
2. For biogas to CHP: cattle manure, poultry manure and sunflower heads.

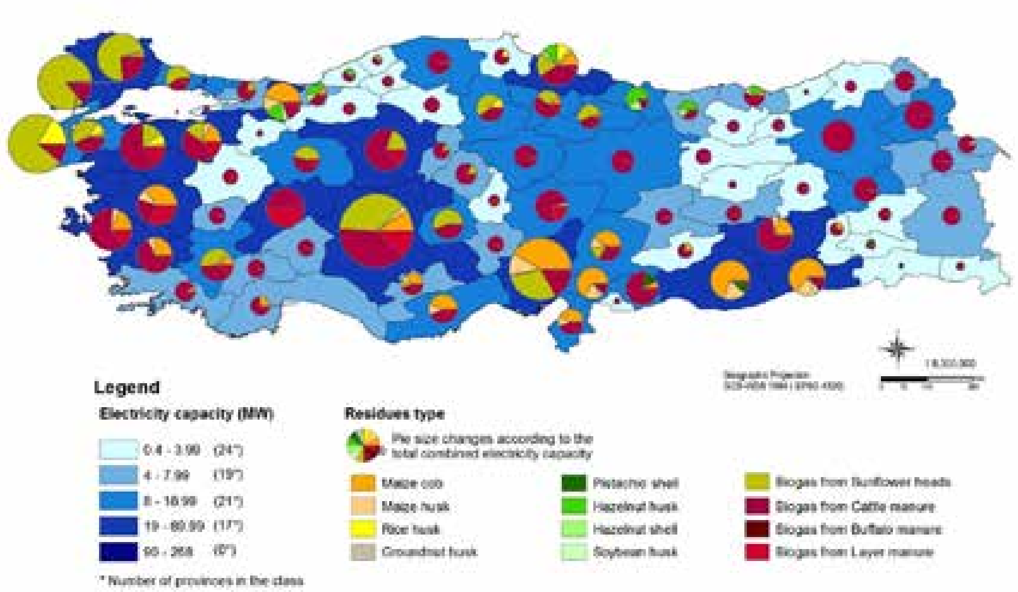
The analysis concludes that it would be possible to reach a combined production capacity of 1 012 MW using the above mentioned residues and technologies This production potential is around 101 percent of the target 1 000 MW of energy to be produced by biomass by 2023 as defined by the REAP. The figure excludes the use of cotton stalk as they are considered as a feedstock for briquetting and pelleting which are discussed later.

Comparison of combined production capacity of CHP alternatives and Turkish renewable energy target for electricity from biomass



The figure below summarizes how the 1 012 MW combined production capacity is generated 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

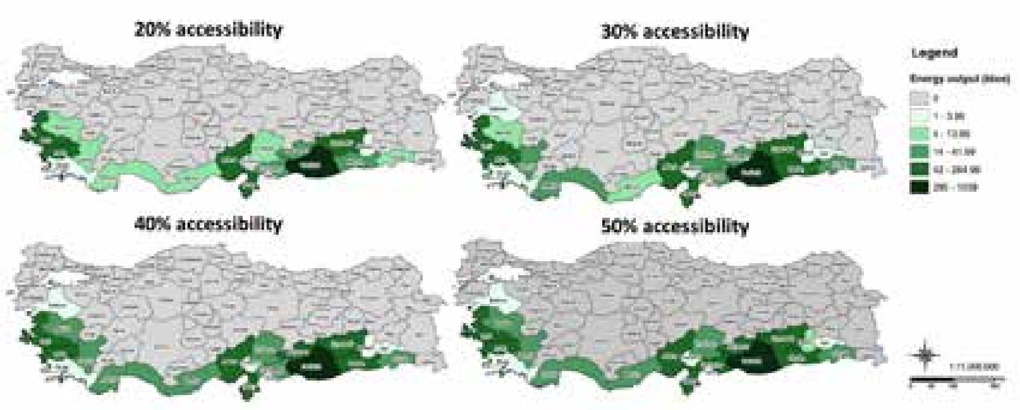
Electricity capacity generation (MW) from crop residues (excluding cotton stalk) and livestock manure biogas



Under a set of specific production conditions and feedstock options, briquetting and pelletizing biomass are promising options to support the achievement of the renewable energy production targets of the country. Hot press technologies are better for medium and large-scale production, while cold press technologies are better for small-scale manual operations. Briquette production is likely to be profitable at all plant sizes, while pellet production is likely to be more profitable at medium and large-scale plant sizes. This means pellet production requires larger investments than briquette production, but would yield larger revenues. Additionally, based on the current heating and cooking demand in Turkey, coal and fuelwood could be replaced by biomass briquettes and pellets. Given this, it is important to take into account the minimum required energy potential and the price ceiling for both briquettes and pellets after considering the region's charcoal and fuelwood consumption and to what extent the competing industry has been established. Based on these conditions, the top 10 most promising crop residues identified as potentially available and profitable include: hazelnut shell and husk, groundnut husk, cotton stalk, maize cob and husk, pistachio shell, soybean husk, sunflower heads and rice husk. However, the accessibility of residues that (proportion of the available residues that can actually be mobilized for energy production) 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 was chosen for this analysis as it is abundantly available in the country.. Given this, if 20 percent of cotton stalk were to be accessed, this would result in producing 1 033 ktoe of energy. Given the Turkish REAP biomass heating and cooling target is set at 3 537 ktoe, the 1 033 ktoe would be equivalent to almost 30 percent of the REAP target. If collection and mobilisation were to be improved for cotton stalk, then there could be potential to fulfil an even larger share the REAP target.

The figure below 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. Furthermore, as accessibility improves the green shaded areas become darker, which is a reflection of the higher amounts of energy being generated. 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, but that this is also tied to the actual amount of residues that can be accessed. By increasing the accessibility levels, the country could reach the national renewable energy targets under options that have been shown to be profitable

Total national potential energy output (ktoe) from cotton stalk at different accessibility levels



Conclusions and Recommendations

Bioenergy has the potential to be a key player among the renewable energy options in Turkey, aiming to a reduction in the short term and substitution in the long term of fossil fuels dependence. According to the energy need of the country it was identified that bioenergy options that supply heating and cooking as well as electricity would have a prime interest. Thus, the potential to convert biomass residues into more efficient fuels such as briquettes and pellets or alternatively directly produce heat and electricity using CHP was the main interest area of BEFS assessment. The results of this assessment indicate that there exists a high potential to supply the renewable energy targets based on the available biomass in Turkey, using efficient technologies and specific profitable production conditions.

Technical meetings and expert workshops were held in Turkey with the lead government counterparts, including country experts in the related fields.

The discussions held throughout the various phases of the workshop and at the final presentation raised the following issues:

1. Lack of knowledge and awareness of biomass, biomass potential which limits the understanding of what potential for bioenergy may exist and where and how to exploit such potential;
2. Lack of technology, although various stakeholder reported on a number of industries starting up in the country;
3. Lack of policy coordination across sectors with related lack of inter-ministerial coordination across relevant bioenergy policy areas in the country, including agriculture, environment and energy policymakers. At times, this can result in bottlenecks in the mobilization and use of the identified net available resources. There is the need for the agriculture, environment and energy policymakers and industry players to agree and coordinate on defining which residues can be used and

are available for use.

The measures discussed and pointed to were the following:

1. Feedstock collection points;
2. Central management platforms for biomass;
3. Need for policy coordination;
4. Clarification of what may be agriculture waste or what may be agriculture residues that could therefore be used for bioenergy; and
5. A system to coordinate feedstock supply to ensure stability of supply.

In the short-term, it is recommended that bioenergy production should focus on those residues that are either already collected in field or at the agro-processing plant. Residues that are already collected have low mobilisation costs as well as high accessibility. It is recommended to identify the most promising feedstock, in terms of quantity available and suitability to be used for CHP, biogas production and for the production of briquettes and pellets. The country can then identify and verify the province with highest availability and accessibility of that feedstock.

In the long to medium term, efforts should be made to develop appropriate policies and mechanisms, to put in place an agricultural residue value chain that ensures a uniform and dependable supply of residues. This should involve cooperatives, intermediaries and a mechanism to encourage information exchange between energy producers and biomass owners as well as policies to introduce mechanization equipment for the collection and pre-treatment of residues and storage facilities.

As an initial step, it would be advisable to conduct a local verification in the selected provinces of optimal choice and the use of these residues, energy needs, competing uses, and local costs, in order to understand the reasons why this potential is not being currently used in the country. The results of this assessment might be used by the country to create an integrated and efficient strategy for the smart use of biomass residues available for bioenergy production at the national level.

CHAPTER 1

INTRODUCTION

Energy is an essential part of modern livelihoods, but modern energy pathways are having strong climate change impacts. As the world continues to develop, the urgency to find alternative energy pathways that can assist in the struggle against climate change and its impacts is becoming stringent. Agriculture has a role to play in this effort both as a user of energy and as a provider of energy. In terms of energy provision, bioenergy, i.e. energy generated from agriculture-based biomass, can be part of a renewable energy strategy that assists countries in diversifying away from traditional fossil fuel use, allowing it to move onto a lower energy consumption pathway.

Bioenergy offers a wide range of options in terms of energy end use ranging from heat, power and transport fuel. Depending on this end use, bioenergy can be derived from agriculture residues, crops and woody biomass. Options can be complex as they closely tie the agriculture sector to the energy sector. The key in this is to accurately assess the options being considered within the country context and, through a country tailored assessment of the potential, define which bioenergy pathways can be sustainable. The role that bioenergy can play in the renewable energy mix can be very diverse both in terms of types and magnitudes. This will depend on the country context, agriculture potential and energy needs. The key element in terms of bioenergy strategy is to build the bioenergy policy on the country evidence generated through this process.

This report was developed under the collaborative agreement between The European Bank for Reconstruction and Development (EBRD) and Food and Agriculture Organization of the United Nations (FAO) within the Sustainable Resource Initiative and building on the Bioenergy and Food Security (BEFS) Approach of FAO.

The EBRD has recently adopted the Green Economy Transition approach. Within this approach, public and private investments are made with a specific concern to minimise the impact of economic activity on the environment and address market failures through improved policy and legal frameworks, aiming at accounting systematically for the inherent value of services provided by nature, managing related risks and catalysing innovation. This approach underlines the role for fast and material changes in an economic space where markets are currently weak or non-existent. Like other aspects of transition, the shift to an environmentally sustainable economy is also centred on the transformation of markets, behaviours, products and processes, deployment of technologies and new skills.

The Sustainable Resource Initiative is EBRD's umbrella initiative which promotes efficiency and innovation in three areas vital for countries where the EBRD invests, namely energy, water and materials. A part of the initiative aims to scale up sustainable

energy investments in the region of operation of the EBRD with a focus on improving the business environment and removing key barriers to market development. In most of the region where EBRD operates, renewable energy still accounts for a relatively small share in the energy mix. EBRD recognizes that renewable energy investments have lagged behind due to relatively high investment costs per kW installed, low energy tariffs, and weak institutional capacity and regulatory frameworks. In response to this, the EBRD has been analysing the potential for renewable energy uptake and increasing financing for wind projects, hydro power plants, biomass and solar projects. In terms of biomass, this approach assists with the transition to a low-carbon economy, in which biofuels are expected to play an important role. Moreover, the approach unlocks new business opportunities, based on innovative technological developments from renewable second-generation biofuels technologies, and the commercial implementation of these technologies.

In order to support decision-making related to bioenergy developments, the FAO has developed a Sustainable Bioenergy Support Package. A core element of the package is the BEFS Approach, which supports countries in designing and implementing sustainable bioenergy strategies. The formulation of these bioenergy policies is based on country level evidence that is developed in close consultation with key country stakeholders and experts. There are six key components in the BEFS Approach:

- Scoping,
- Stakeholder Dialogue and Capacity Building,
- Sustainable Bioenergy Assessment,
- Support to Policy Formulation,
- Impact Monitoring, Evaluation and Response, and
- Risk Prevention, Management and Investment Screening.

Depending on the areas of interest, the level of bioenergy development, and the status of bioenergy policy formulation and implementation, countries may decide to use specific components of the BEFS Approach.

In order to ensure evidence-based bioenergy policies, the BEFS Approach has two levels to conduct a sustainable bioenergy assessment. This covers the whole bioenergy pathway starting from feedstock availability assessment to energy end use options. There is an initial assessment level named the BEFS Rapid Appraisal and a more in-depth level named the Detailed BEFS. The first step is the BEFS Rapid Appraisal (BEFS RA) as it can be carried out in a short timeframe and can provide policy makers with an initial understanding of the bioenergy potential in a specific country context along with the potential risks and benefits, economic viability and key social indicators.

OBJECTIVE, SCOPE AND STRUCTURE OF THE REPORT

The scope of this report is to provide an initial assessment of the availability and the potential use of agricultural residues in Turkey for the production of heat, power or combined heat and power. The specific agriculture residues covered in detail are crop residues and livestock residues.

To accomplish this assessment, the tools and methodology of the BEFS Approach, including the sustainable biomass assessment and the BEFS Rapid Appraisal tools, were utilised. Country-specific data and conditions were used in the analysis.

The analysis is carried out at province level and builds as much as possible on previous analysis carried out in Turkey and on ongoing efforts related to bioenergy potential assessment from agriculture residues.

The report is structured in five parts. The first section provides some context and background on the country, including the agriculture and energy sectors in Turkey, and on the current agriculture and energy policies already in place.

The second section covers the assessment of the biomass potential from crop residues and livestock residues. Whenever possible, availability is quantified and qualified, while accessibility issues are qualified as outlined in the section.

The third section covers the techno-economic and some socio-economic assessment of the energy end use options that relate to the production of heat, electricity or combined heat and power from the agriculture residues. The biomass used in these pathways is derived from the biomass assessment results from section two. The energy end use options considered are briquettes, pellets, and large-scale combined heat and power from direct combustion or from biogas.

The fourth section assesses the availability of agro-processing residues carried out through a short questionnaire conducted among agro-food and wood processing facilities

The final section of the report provides an overall set of conclusions and recommendations for next steps based on the outcome of the analysis.

COUNTRY CONTEXT

Turkey lies at the junction of Europe, Asia and the Middle East, and covers an area of 783 562 square kilometres. Its territory is composed of a high central plateau (Anatolia), a narrow coastal plain and several mountain ranges. Turkey is divided into 7 geographical regions: Black Sea, Marmara and Thrace, Aegean, Mediterranean, Central Anatolia, Eastern and Southeastern Anatolia. The total population is 74.9 million, with 72 percent concentrated in urban areas (IFAD, 2014).

This strategic geographical location, combined with a large domestic market and a stable macroeconomic policy, have enabled Turkey to become the seventeenth largest economy in the world in terms of GDP at about USD 800 billion in 2014. National income per capita in the country has nearly tripled during the last 10 years and exceeds USD 10 500 (World Bank, 2016). Turkey is a dynamic economy with a mix of modern industry and commerce and a traditional agriculture sector, which accounted for about 19.7 percent of employment in 2014 (UNDP, 2014; World Development Indicators, 2016).

Following the 2001 economic crisis, Turkey put in place an ambitious structural reform agenda, along with sound monetary, fiscal and financial sector policies. The aim has been to establish macroeconomic and financial stability, and to improve the overall investment environment for sustainable growth (Macovei, 2009). Turkey has experienced high and variable inflation since the 1970s, however the inflation rate has decreased from 104.5 in 1994 to single digits in the past decade, remaining around the 6-10 percent interval (World Economic Outlook, 2015; Central Bank of the Republic of Turkey, 2014). Respectively, the consumer price index increased from 19.3 in 2000 to 135.7 in 2014[1] (World Development Indicators, 2016). The Central Bank of Turkey has set out to decrease inflation to 5 percent since 2012, and is striving to meet that goal by tackling food inflation which has been a significant risk factor in the level and volatility of headline inflation (Central Bank of the Republic of Turkey, 2014). Turkey has averaged growth rates of 3-4 percent in the past decade and is expected to become a high-income status country in the next decade due to its young population, substantial investment opportunities and improved education attainment (World Bank, 2014). Furthermore, Turkey's open and free-market economy has allowed the country to integrate with the global economic and financial system (Ministry of Foreign Affairs, 2011a).

Agriculture Sector

Turkey is the seventh largest agricultural producer in the world (OECD, 2011b), with the share of agriculture in GDP declining 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. In the 2006-2008 period, crop production represented 66 percent of the total value of agricultural output, while animal products made up 22 percent and livestock constituted 12 percent. The large agricultural sector accounted for about 25 percent of total employment in 2009 (OECD, 2011b).

Agriculture 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 export value). These commodities comprise a 43 percent share in total value of exports in 2011. However, each commodity share contributes less than 8 percent of the total export value, demonstrating that export values are spread out and markedly varied (Table 1) (FAOSTAT, 2015). The country has experienced severe droughts, and Turkish agriculture, especially cereal production, is heavily dependent on seasonal rainfall (Dellal and McCarl, 2010; FAO, 2015; Kurnaz, 2014; Kibaroglou, Kramer, & Scheumann, 2011).

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[1] The base year is 2010 at a consumer price index of 100 (World Development Indicators, 2016).

TABLE 1.

Agricultural trade – Key commodities (2011)

RANK	TRADE COMMODITY	EXPORT QUANTITY (t)	EXPORT VALUE (1 000 US$)	EXPORT UNIT VALUE (USD/t)	SHARE IN TOTAL VALUE OF EXPORTS
1	Hazelnuts	146 322	1 041 429	7 117	7.4%
2	Wheat Flour	2 062 730	933 534	453	6.6%
3	Food Preparations*	260 149	723 589	2 781	5.1%
4	Nuts**	106 552	637 659	5 984	4.5%
5	Pastries	283 620	618 275	2 180	4.4%
6	Raisins	214 086	506 499	2 366	3.6%
7	Chocolate***	149 398	433 839	2 904	3.1%
8	Tomatoes	576 573	432 461	750	3.1%
9	Chicken Meat	234 148	380 772	1 626	2.7%
10	Tobacco (unmanufactured)	68 031	369 464	5 431	2.6%
	TOTAL	-	6 077 521	-	43%

*Includes both crops and livestock products (among other things, homogenized composite food preparations; soups and broths; ketchup and other sauces, etc.). Does not include food preparations of flour, meal, starch, malt extracts or milk.

**Prepared, mainly roasted nuts. Excludes groundnuts.

***Includes sweetened cocoa powder, chocolate and other food preparations containing cocoa.[2]

Source: FAOSTAT, 2015

The livestock sector is made up of small-scale farms and domestic breeds, which are not very productive but have the ability to adapt to the harsh climate of eastern Turkey. Demand for meat products is increasing, however the livestock sector has been facing a decrease in the number of cattle, sheep and goat herds. Moreover, the 2008 milk crisis in the country brought about the slaughter of dairy herds, further reducing the number of cattle and causing an increase in red meat prices since late 2009 (Serttas, 2010). The Ministry of Food, Agriculture and Livestock will permit the import of feeder cattle from certain countries in order to increase the capacity of local producers (Duyum, 2015a and 2015b).

In terms of food security and key food crops for the country, the major foodstuff was wheat, which contributed 35.6 percent to the total food supply in 2011. The remaining foodstuffs each contributed less than 8 percent of the total food supply for that year. More specifically, the total average calorie consumption was 3 680 calories/capita/day in 2011, with wheat, sugar, milk, sunflower seed oil and maize making up more than 60 percent of the total calories consumed (Table 2) (FAOTSTAT, 2015).

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[2] Refer to FAOSTAT definitions, available at http://faostat.fao.org/site/385/default.aspx, for clarification on commodity classifications.

TABLE 2.

Food supply and key foodstuffs (2011)

RANK	FOOD COMMODITY	FOOD SUPPLY (kcal/capita/day)	SHARE IN TOTAL FOOD SUPPLY
1	Wheat and products	1 311	35.6%
2	Sugar (raw equivalent)	290	7.9%
3	Milk (excluding butter)	265	7.2%
4	Sunflower Seed Oil	238	6.5%
5	Maize and products	143	3.9%
	TOTAL	2 247	61.1%

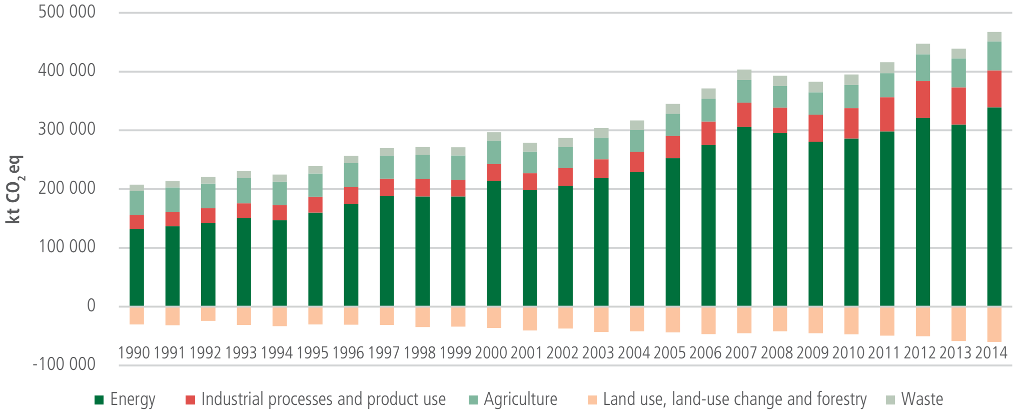
Source: FAOSTAT, 2015

Average farm sizes remain small in the country and there are 3.1 million farm households on a total of 23 million hectares of land. More than half of these farm households (57.5 percent) occupy less than 4.9 hectares of land, which translates into 16.1 percent of the total agricultural land. Additionally, 40.7 percent of the farm households occupy between 5 - 49.9 hectares of land, which takes the biggest share of the total agricultural land at 62.7 percent. The remaining farm households (1.8 percent) hold 50 or more hectares of land, which is equivalent to 21.1 percent of the total agricultural land. Small-scale farms are characteristic of the Turkish livestock sector where, according to the 2006 Agricultural Holding Structure Survey, 60 percent of households have 1 to 4 bovine animals and only 2 percent of households have more than 150 bovine animals (OECD, 2011b).

Total national greenhouse gas (GHG) emissions in Turkey in the period from 1990-2014 are presented in Figure 1. The data show that emissions (excluding land use, land-use change and forestry (LULUCF)) have more than doubled over the period concerned and an increase is recorded within each sector. The main driver for such an increase is actually within the energy sector where emissions went from 132 477 kt CO_2eq in 1990 to 339 105 kt CO_2eq in 2014 and whose contribution to national emissions is most significant (64 percent in 1990 to 73 percent in 2014). Large increases are also seen in the industrial processes sector, but it does not have the level of significance as the energy sector has in terms of relative share in the total emissions. In regards to the agriculture sector, associated emissions have also increased by 20 percent between 1990 and 2014, although its relative share in total national emissions has decreased (from 19.8 percent in 1990 to 10.6 percent in 2014) (National Inventory Submissions, 2015).

FIGURE 1.

GHG emissions from all sectors

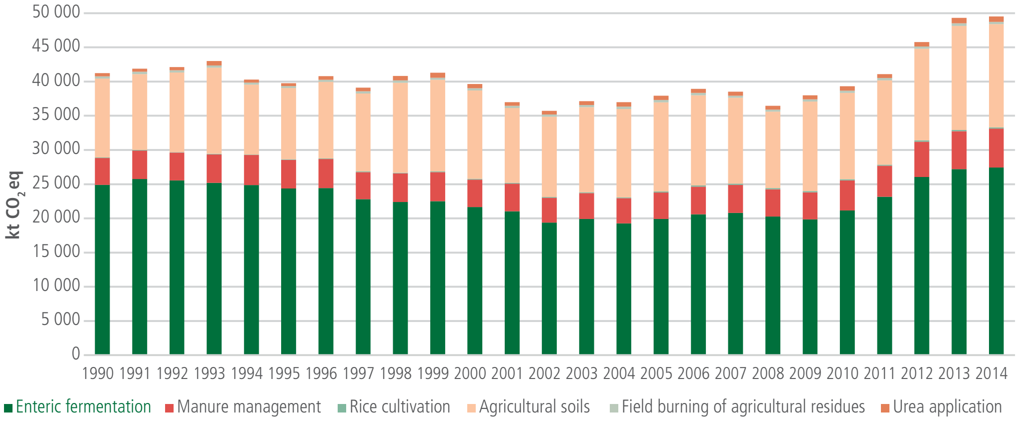


Source: National Inventory Submissions, 2015

Figure 2 shows the GHG emission trend from 1990 to 2014 for the agriculture sector in Turkey. Certain fluctuations can be noticed between 1990 until 2008, but from 2008 onwards, there is a steady increase. Relative shares in each subsector have not changed significantly. The agricultural subsector that contributes the most to these sectoral emissions is enteric fermentation, which is directly linked to the amount of livestock in the country. Another important subsector is agricultural soils. Within this subsector, the main driver for GHG emissions, in terms of N_2O, is the application of inorganic nitrogen fertilizers followed by crop residues (Figure 3). GHG emissions associated with the burning of residues in the field are below 1 percent of emissions in the agriculture sector and these emissions have decreased in the period concerned.

FIGURE 2.

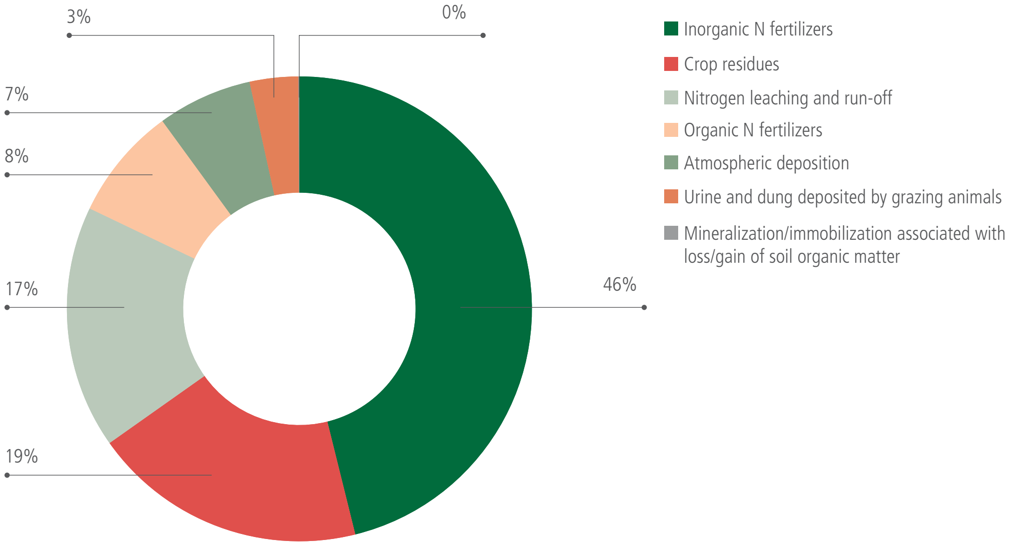
GHG emissions from the agriculture sector



Source: National Inventory Submissions, 2015

FIGURE 3.

Contribution of specific categories to N_2O emission in agricultural soil subsector



Source: National Inventory Submissions, 2015

Agricultural policy

Turkey's main agricultural policy targets, as outlined in the Agricultural Law of 2006 (No. 5 488), are as follows: meeting the food security needs of a growing population; increasing productivity and reducing vulnerability to adverse weather conditions; improving self-sufficiency levels; raising farm incomes while providing greater stability; increasing competitiveness; developing rural areas; ensuring food safety; and bringing the country's agricultural and rural development policies and institutions into alignment with those of the EU. Until the early 2000s, these targets were addressed through price supports for commodities complemented by trade-related measures (particularly tariffs) and farm input subsidies. Since 2009, agricultural supports have continued but in the form of area and commodity-based payments (OECD, 2011a and 2011b).

On July 2013, Turkey enacted the 10th development plan for 2014-2018. The main objective outlined for the agriculture sector is to develop a globally competitive and environmentally friendly sector that can provide sufficient and balanced nutrition to the population. Current challenges faced include small and fragmented agricultural businesses, insufficiencies in market access and lack of extension and training services for farmers (Ministry of Development, 2014).

Moreover, the 2013-17 Strategic Plan of the Ministry of Food, Agriculture and Livestock defines five strategic areas in the agricultural sector:

- agricultural production and supply security,
- food safety,
- phytosanitary, animal health and welfare,
- agricultural infrastructure and rural development; and

- institutional capacity building (Ministry of Food, Agriculture and Livestock, 2015).

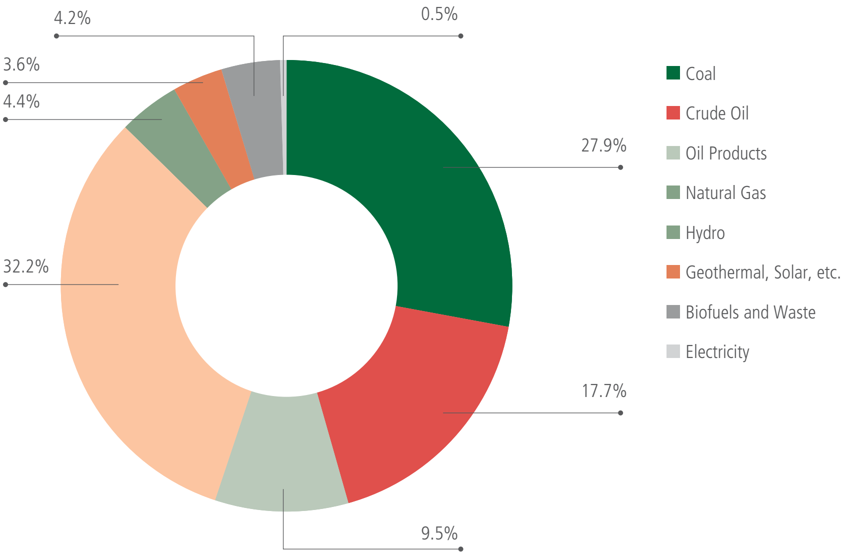
The Turkish Ministry of Development forecasts that the average annual growth rate of the agriculture sector will be 3.1 percent, the share of agricultural employment in total employment will decrease to 21.9 percent and the share of agriculture sector in GDP will be 6.8 by 2018 (Ministry of Development, 2014).

Energy Sector

Turkey relies heavily on fossil fuels to meet its domestic energy demand, as fossil fuels make up approximately 88 percent of the total primary energy supply (tpes) (Figure 4). Moreover, around 82 percent of the tpes was imported in 2013, illustrating that the country relies heavily on imports. The majority of the imports comprised of oil and natural gas at about 80 percent (Table 3) (IEA, 2016).

FIGURE 4.

Total primary energy supply in Turkey (2013)



Source: IEA, 2016

TABLE 3.

Energy balance in Turkey (ktoe) (2013)

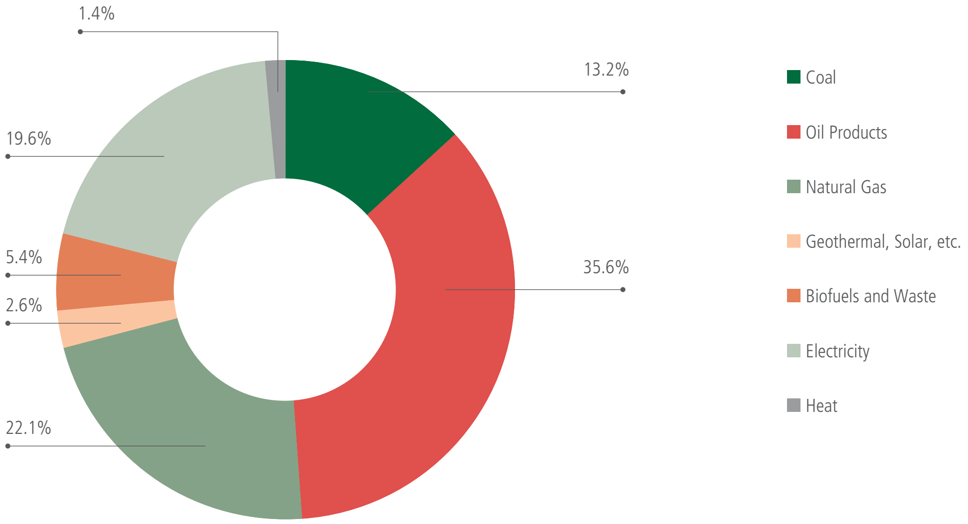
	Coal	Crude Oil	Oil Products	Natural Gas	Hydro	Geo-thermal, solar, etc.	Biofuels and waste	Electricity	Tot.
Production	15 674	2 370	-	443	5t110	4 192	4 556	-	32 346
Imports	17 826	18 487	21 011	37 263	-	-	340	639	95 566
Exports	9	209	8 012	561	-	-	-	106	8 897
TPES	32 515	20 569	11 124	37 545	5 110	4 192	4 897	533	116 485

Source: IEA, 2016

Oil products, natural gas and coal account for more than 70 percent of the final energy consumption in the country (Figure 5).The leading primary energy consumer is the industry sector at 28.5 percent, closely followed by the residential sector at 24.3 and transport at 22.2 percent (Table 4) (IEA, 2016).

FIGURE 5.

Final energy consumption in Turkey (2013)



Source: IEA, 2016

TABLE 4.

Total final consumption and relative shares in Turkey (2013)

SECTOR	FINAL ENERGY CONSUMPTION (ktoe)	SHARE OF TOTAL ENERGY CONSUMPTION (percent)
Industry	24 497	28.5
Transport	19 122	22.2
Residential	20 864	24.3
Commercial and public services	10 199	11.9
Agriculture	4 256	4.9
Other (excluding the above)	7 078	8.2
TOTAL	86 017	100

Source: IEA, 2016

Turkey's natural resources face increasing pressures from the increase in energy use in the industry, transport, tourism, and agriculture sectors which have resulted in water stress, soil erosion and pollution. Average life expectancy has also increased, placing additional demands on energy supply systems. Additionally, improvements in the standard of living have increased domestic energy demand and forecasts predict that this will continue to rise (IEA, 2009).

Energy policy

The country's principal objective is energy security, therefore Turkey aims to: diversify its energy supply routes and source countries; increase the share of renewables to the highest possible extent and include nuclear into its energy mix; make steps towards improved energy efficiency; and contribute to Europe's energy security. Turkey estimates that there will continue to be immense growth in energy demand and wants to meet this demand in a manner that is timely, adequate and affordable. The government is also improving the investment environment for the private sector by taking steps towards the liberalization of the electricity and natural gas markets (Ministry of Foreign Affairs, 2011b; Ministry of Development, 2014).

Furthermore, Turkey has substantial potential for renewable energy resources and the country aims to increase its use of geothermal, hydro, wind and solar energy resources as well as reducing its dependency on imported fossil fuels through slowly commissioning nuclear power into the mix. The country plans to have more than 10 000 MW in nuclear capacity by 2030 and has already signed an intergovernmental agreement with the Russian Federation on the construction of a nuclear plant. Additionally, two other constructions on nuclear energy plants are envisaged (Ministry of Foreign Affairs, 2011b). Turkey also has in place the 2007 Energy Efficiency Law (No. 5 627) to increase the energy use efficiency and use domestic resources in a sustainable manner. This was further expanded in the strategy document on efficiency in 2012, which aims to reduce energy intensity by at least 20 percent in 2023 (with reference to 2011 figures) (Ministry of Development, 2014; Ministry of Energy and Natural Resources, 2014; European Environment Agency, 2011).

The development of renewable energy sources and the promotion of energy efficiency are the main tenets of Turkey's energy agenda as articulated in the Renewable Energy Action Plan (REAP) and the forthcoming National Energy Efficiency Action Plan (NEEAP). The REAP for Turkey has been created in alignment with 'the Renewable Energy Directive' Directive 2009/28/EC of the European Parliament and of the Council. This is an action plan for Turkey and is a manifestation of its commitment to the renewable energy targets set out by the EU. REAP has set a target to produce 20 percent of its total energy consumption from renewable sources by 2023. More specifically, it envisages producing at least 30 percent of its electricity and 10 percent of its transport energy consumption from renewable sources by 2023. Additionally, there is also a commitment to reduce the amount of energy consumed per unit GDP in the year 2023 (in terms of energy intensity) by at least 20 percent (with reference to 2011 figures). The country also has technology specific targets and aims to produce 1 000 MW from biomass alone by 2023, compared to 224 MW in 2013 (Table 5) (Ministry of Energy and Natural Resources, 2014). The role of biomass is much smaller when compared to hydropower and wind. In fact, considering the installed electricity capacity target for 2023, the objective is to add 34

GW of hydropower, 20 GW of wind energy, 5 GW of solar energy, 1 GW of geothermal and 1 GW of biomass (Table 5) (Ministry of Energy and Natural Resources, 2014).

TABLE 5.

Estimate energy shares from renewable energy sources in electricity (installed capacity and gross electricity generation)*

	2019**		2020		2021		2022		2023	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Hydropower	32 000	86 400	32 500	87 750	33 000	89 100	33 500	90 450	34 000	91 800
Geothermal	706	3 599	779	3 975	853	43 50	926	4 725	1 000	5 100
Solar***	3 000	4 800	3 600	5 760	4 000	6 400	4 400	7 040	5 000	8 000
Wind****	13 308	33 270	15 090	37 725	16 800	41 999	18 436	46 089	20 000	50 000
Biomass	683	3 126	759	3 477	836	3 829	912	4 181	1 000	4 533
Total	49 697	131 196	52 729	138 687	55 488	145 678	58 174	152 485	61 000	159 433

*The original document has estimates starting from 2013. In this table, estimates from 2019 onwards are shown.
**The 2005-2019 Strategic Plan slightly changed the targets for 2019: biomass increased to 700 MW from 683 MW, while geothermal decreased to 700 MW from 706 MW and wind decreased to 10 000 MW from 13 308 MW. However, we used the 2023 targets as the basis for our assessment and these numbers do not affect our overall results (Ministry of Energy and Natural Resources, 2015).
***photovoltaics
****land-based

Source: Ministry of Energy and Natural Resources, 2014

Biomass is the largest contributor towards the REAP heating and cooling target, but it stays fixed at 3 537 ktoe (Table 6) (Ministry of Energy and Natural Resources, 2014).

TABLE 6.

Estimate energy shares from renewable energy sources in heating and cooling (ktoe)

(ktoe)	BASE YEAR	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Geothermal*	329	344	358	372	386	400	414	428	443	457	471	485
Solar Energy	630	644	659	673	687	702	716	730	745	759	773	788
Biomass (solid)	3 537	3 537	3 537	3 537	3 537	3 537	3 537	3 537	3 537	3 537	3 537	3 537
RE Heat Pumps (geothermal)	1 657	1 729	1 800	1 871	1 942	2 013	2 084	2 155	2 226	2 297	2 369	2 440
Total	6 154	6 254	6 353	6 453	6 553	6 652	6 752	6 851	6 951	7 050	7 150	7 249

Source: Ministry of Energy and Natural Resources, 2014

Lastly, for the transport sector the estimated total contribution for bioenergy increases steadily over the 10-year period. Ethanol goes from 127 ktoe in 2013 to 886 ktoe in 2023, while the share of biodiesel increases from 33 ktoe in 2013 to 1 319 ktoe in 2023 (Table 7) (Ministry of Energy and Natural Resources, 2014). Bioenergy will play a significant role in the transport sector targets, however this report does not focus on the transport chain as its focus is on electricity and heating.

TABLE 7.

Estimate energy shares from renewable energy sources in the transport sector (1 000 toe)

(ktoe)	BASE YEAR	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Bioethanol/ ETBE	18	127	195	272	352	440	529	623	723	830	857	886
Biodiesel	9	33	57	81	105	218	338	522	718	988	1 148	1 319
Electricity*	10	11	12	13	14	16	17	18	19	19	20	20
(in road transport)	3	3	3	3	3	4	4	4	4	4	4	4
(not in road transport)	7	8	9	10	1	12	13	14	15	15	16	17
Total	37	171	264	366	471	674	883	1 163	1 459	1 837	2 025	2 226

*from renewable energy sources

Source: Ministry of Energy and Natural Resources, 2014

The 2015-2019 Strategic Plan of the Ministry of Energy and Natural Resources sets out the main priorities for energy policy, which include:

- Reduction of energy dependency on imported fossil fuels, which given the price volatility of non-renewables has effects on the pace of national economic development.
- Additional energy capacity to supply the estimated demand growth for energy of 75 percent between 2012 and 2023. This increase in capacity is envisaged to be achieved through increases in natural gas, nuclear generation capacity and an increase renewable energy electricity generation to at least 30 percent of the total energy supply.
- Improvement of transmission grid infrastructure.
- Improvement of energy efficiency in the electricity transmission grids.
- Working more closely with the agricultural sector to develop biofuels (biodiesel and bioethanol) (Ministry of Energy and Natural Resources, 2014).

In the most recent Strategic Plan of 2015-2019, the Ministry of Energy and Natural Resources, reiterated its mission is to “provide the highest contribution to national welfare by utilising energy and natural resources in the most efficient and environmentally-conscious manner”. It includes eight overall themes:

- Security of Energy Supply,
- Energy Efficiency and Energy Saving,
- Good governance and Stakeholder Interaction,
- Regional and International Effectiveness,
- Technology, R&D and Innovation,
- Improvement of the Investment Environment,

- Raw Material Supply Security, and
- Efficient and Effective Use of Raw Material.

Specifically, under the theme of security of energy supply, the Ministry reaffirms the potential in using renewable energy sources, such as solar, wind, hydro-electric, geothermal, biomass, wave and tidal, for the generation of electricity and heat. Moreover, the Ministry acknowledges that to tap into this potential, investor awareness and financial opportunities need to be increased, transmission infrastructure must be strengthened and legislature updated (Ministry of Energy and Natural Resources, 2015).

CHAPTER 2

NATURAL RESOURCE ASSESSMENT

The objective of the Natural Resource Assessment is to estimate the amount of agricultural residues that can be potentially available for energy production, and indicate their accessibility. The analysis is helpful in identifying the main residue type available for bioenergy production as well as their geographical distribution within Turkey.

The analysis focused on primary crop residues such as cereal straw, maize, sunflower and cotton stalks, and secondary crop residues, such as rise husk, sunflower heads and nutshells. In the case of livestock residues, the analysis focused on cattle and chicken manure.

FIGURE 6.

Residues analysed in the assessment

METHODOLOGY FOR THE ASSESSMENT

The assessment was conducted following the Bioenergy and Food Security Approach, more specifically the Bioenergy and Food Security Rapid Appraisal (BEFS RA) methodology (FAO, 2014). The analysis was carried out at province level based on the data published by the Turkish Statistical Institute (TUIK) for 81 provinces. Agricultural residues comprise of both crop residues as well as livestock residues. Both livestock and crop residues are produced in varying quantity depending on the crop type or animal breed. They also have varying uses from country to country and from region to region within a country. Many crop residues for instance are used as soil amendment or as packaging materials while livestock residues, primarily manure, is used as organic fertilizer. As a result, the use of agricultural residues for bioenergy production must be done in a way that avoids any negative impact on any existing uses.

This assessment therefore follows three levels of analysis:

I. Production of residues is the amount of residues produced every year based on the quantity of crops produced.
II. Availability of residues is the amount of residues that are potentially available for bioenergy production after deducting the total production of residues from all other, current competing uses.
III. Accessibility of residues is the amount of residues that can practically be mobilised for bioenergy production.

The successful completion of the three levels of analysis is dependent on the availability of crop or livestock specific data. When calculating the second step (availability of residues), it is necessary to have accessible data on the amount of residues already used. A more detailed description of the steps of the analysis for crop and livestock residues is provided in the following sub-section.

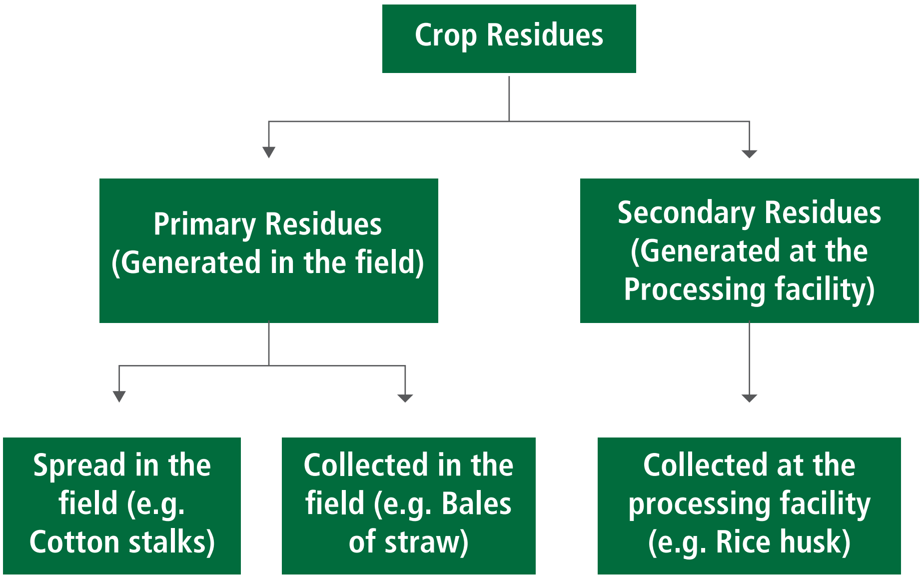
Crop residues

Crop residues are the organic material produced as by-products from harvesting and processing of agricultural crops. They can further be categorized as primary and secondary residues.

- Primary residues are those generated in the field at the time of harvest. They can then be collected in the field, such as cereal straw (when baled) or can be spread in the field, as is the case with sugarcane tops, cotton and maize stalks.
- Secondary residues are those that are co-produced during processing. These include paddy husk, bagasse, maize cob, coconut shell, coconut husk, etc. Secondary residues are collected at a processing facility.

FIGURE 7.

Crop residue types and location



Step 1: Production of crop residues

The amount of crop residue produced depends on the:

- Main crop production
- Crop specific Residue to Crop Ratio (RCR)[3].

The initial selection of crops and related crop residues to be analysed in the assessment was based on two criteria:

- The scale of production of the specific crop in Turkey, and
- The suitability of their residues to produce briquettes and pellets as well as to be used as feedstock for direct combustion, CHP and/or biogas technologies.

The scale of production, which included the amount (tonnes) of crop produced and the corresponding harvest area (hectares) per province, was taken from TIUK[4]. A five-year average (2010-2014) was used as the basis for the analysis to reduce uncertainty due to annual changes in production volumes. The identified list of crops and corresponding residues is given in Table 8, and include straw from cereals, residues from rice and maize, oilseeds, sugar beet, nuts, fruits, cotton, tobacco, etc. as well as some crops grown in greenhouses. The crops are categorized as cereals, oilseeds, fruits (nuts), sugar crops, cash crops and greenhouse vegetables.

TABLE 8.

Initial list of selected crops and corresponding residues

CROP	RESIDUE TYPE	CROP	RESIDUE TYPE	CROP	RESIDUE TYPE
Cereals		Oilseeds		Sugar crops	
Barley	straw	Soybean	stalk	Sugar beet	tops
Wheat	straw		straw		leaves
Triticale	straw		husk	Cash crops	
Rye	straw	Sunflower	stalk	Cotton	hull
Oats	straw		head		stalk
Rice	straw	Groundnut	husk	Tobacco	stalk
			shell		
	husk	Olive	kernel	Residues of vegetables produced in greenhouses	
Maize	stover	Fruit (nuts)			
	cob	Pistachio	shell	Artichoke	Green Beans
	husk	Almonds	shell		
Pulses		Walnut	shell	Broccoli	Green Peas
Chickpea	husk	Hazelnut	shell	Cauliflower	Okra
			husk	Cucumber	
		Apricots	shell/kernel	Eggplant	Tomatoes
		Chestnut	shell		

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[3] RCR is defined as the ratio of the amount of residue generated to the amount of the main product of the crop (e.g. ratio of straw and grain in the case of cereals).

[4] www.turkstat.gov.tr/PreTablo.do?alt_id=1001.

Based on the 5-year average crop amount produced at the province level, the total amount of crop residues produced per province was calculated using the following equation:

$$CR_{tot} = \textit{Crop production quantity (tonnes)} * RCR$$

Where:

CR_{tot} ,[t/year] =total crop residues produced in the area
RCR =Residue to crop ratio of the specific crop

The values of residue-to-crop ratio (RCR) used for the analysed crops were obtained and verified in two steps. The initial values were collected through a literature review and then validated in consultation with relevant national experts in TAGEM[5] in Turkey.

Step 2: Availability of crop residues

The CR_{tot} quantifies the total amount of crop residues produced in a given province. However, not all residues produced are available to be used as feedstock for bioenergy production. Agricultural residues are highly important sources of biomass for both the domestic and industrial sectors and hence are used for various purposes, such as soil amendment and as animal feed. Therefore, the availability of residues for energy application can vary significantly depending on current uses, which can then also vary substantially across provinces.

The bioenergy residue potential is the quantity of residues that can be used to produce bioenergy without affecting other sectors where residues are already used. This can be calculated using the formula:

$$CR_{be} = (CR_{tot} - CR_{soil} - CR_{used})$$

Where:

CR_{be} ,[t/year] =crop residues available for bioenergy production in the area
CR_{tot} ,[t/year] =total crop residues produced in the area
CR_{soil} ,[t/year] =amount of residues that should be left in the field
CR_{used} ,[t/year] =amount of crop residues already used

The amount of residues that should be left in the field depends on the soil type and structure (content of soil organic carbon, nutrients, rock weathering), level of inputs (chemical, organic fertilizers), agricultural practice (crop rotation, tillage) and the crop cultivated (nutrient uptake, content of nutrients in the residues and root system). The amount of residues used for other purposes depends on the availability of other resources, activities and the socio-economic conditions of the population in the area.

The relevant experts at TAGEM first provided the initial values for the availability of crop residues specifically for bioenergy production. These values were then discussed

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[5] The General Directorate of Agricultural Research and Policy of the Ministry of Food, Agriculture and Livestock of the Republic of Turkey.

and validated during the BEFS Technical Consultation, which took place at TAGEM's premises in April 2015[6].

Step 3: Accessibility of crop residues

Even when large amounts of crop residues are available, collecting and mobilising them for bioenergy production can be challenging. Hence, the concept of accessibility is important, which aims to identify the proportion of available crop residues that can actually be used for bioenergy production.

The accessibility of residues relies heavily on their location. Primary residues that are spread in the field are difficult and costly to collect. Due to this, they are preferred over collected residues to be used as soil amendment and as mulch, which helps to conserve moisture, improves the fertility and health of the soil and reduces weed growth. Nevertheless, in many places they are burnt to quickly and cheaply prepare the field for the next cropping season. However, those primarily residues that are collected in the field, such as hay or straw, and are baled have relatively high accessibility. Secondary residues are usually available in relatively large quantities at the processing site and may be used as energy source for the same processing plant involving minimal transportation and handling costs. These residues include rice husks, maize cob, sunflower head, etc. The accessibility of residues also depends on the logistical infrastructure such as road and rail network, which has a significant impact on collection and transportation costs. In theory, accessibility of residues can be calculated using the following formula:

$$CR_{ac} = CR_{be} * k$$

Where:

CR_{ac} ,[t/year] =crop residues accessible for bioenergy production in the area

CR_{be} ,[t/year] =crop residues available for bioenergy production in the area

k,[%] =accessibility coefficient

The accessibility coefficient is determined by a number of parameters, such as harvesting method and type of machinery used (if any), labour availability for residues collection, existence and type of transport infrastructure, existence and size of storage facilities in the area, etc. The accessibility of residues is of high importance in determining the optimal location of placing a bioenergy facility and its economic viability.

Livestock residues

Manure is a by-product of livestock production. Unlike crop residues, manure production is not categorised as primary or secondary residue and can be used for energy production with minimal pre-treatment. The main livestock types assessed in the report are cattle and chicken due to their importance as a source of household income in Turkey

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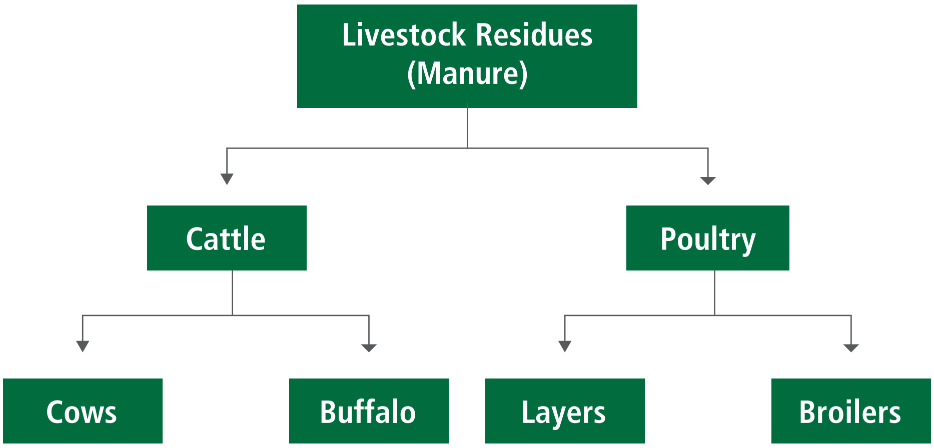
[6] In addition to the data validation, the consultation also included a discussion on the past and foreseen trends in crop production, considering national medium- and long-term agricultural policy, the structure of agricultural sector and market dynamics. Additionally, to address relevant aspects of the sustainable use of residues for bioenergy, 15 experts from several research institutes, academia and private sector participated in the consultation. The participants had expertise in the production and management of cereals, oilseed, hazelnut and cotton production and processing as well as on soil stability protection (erosion), cattle production and food processing.

as well as the recent rise in cattle and chicken population (see section on 'Livestock Production Information' in Annex).

FIGURE 8.

Livestock types covered in the assessment.



Due to lack of data on the current uses of manure, the livestock residue analysis was limited to estimating province level manure production (Step 1 of the analysis). The amount of manure produced depends on several factors including animal type (ruminant or non-ruminant), diet (forage-based or grain-based), animal age (which can influence the amount of feed consumed), animal productivity as well as other factors. Therefore, when estimating the manure production, specific data on breed, age and gender of the cattle was taken into account.

Step 1: Production of livestock manure

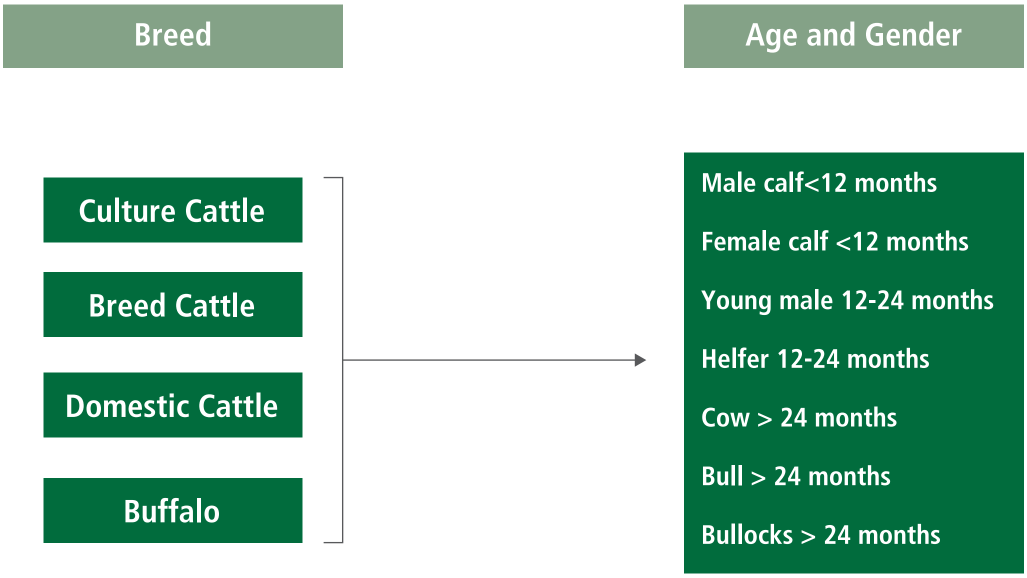
Total manure production per province is based on the:

- Type and Number of animals (cattle or poultry)
  - For cattle, it is also important to know the breed, age and gender of the animal, while for poultry a distinction needs to be made between layers and broilers.
- Manure produced per head per year.

Turkish cattle can be divided into 4 categories, which are further divided into 7 subcategories depending on age and gender (Figure 9).

FIGURE 9.

Type of cattle analysed



The amount of manure produced was then calculated using the following equation:

$$LR_{tot}=N_{an}*M_{ph}$$

Where:

LR_{to} ,[t/year] =Total manure produced per year in the area
N_{an} ,[t/year] =Number of animal (per cattle and poultry type) in the area
M_{ph} ,[t/year] =Amount of manure produced per head per year

The value for ‘manure produced per head’ for each type of cattle and poultry was determined through a technical consultation with experts from TAGEM as well as data available publically through BEPA.[7]

Step 2: Availability of livestock residue

Manure is a valuable material that can be used as a source of organic matter and fertilizer for crop and pasture production. Manure can also be used as a source of energy on the farm through anaerobic digestion to produce biogas to then produce heat and/or electricity. The actual manure used as bio-fertilizer can vary substantially from region to region. Due to the lack of information on current manure usage in Turkey, the availability of manure for bioenergy production could not be estimated.

Step 3: Accessibility of livestock residues

Accessibility of livestock residue depends largely on the size of animal holding as well as the systems of manure management. The type of manure storage and handling systems is important to efficiently collect and utilize the produced manure. Manure collection systems are dependent on many factors such as bedding type, system of rearing, etc. However, they require substantial financial investment. A large farm could possibly be in a

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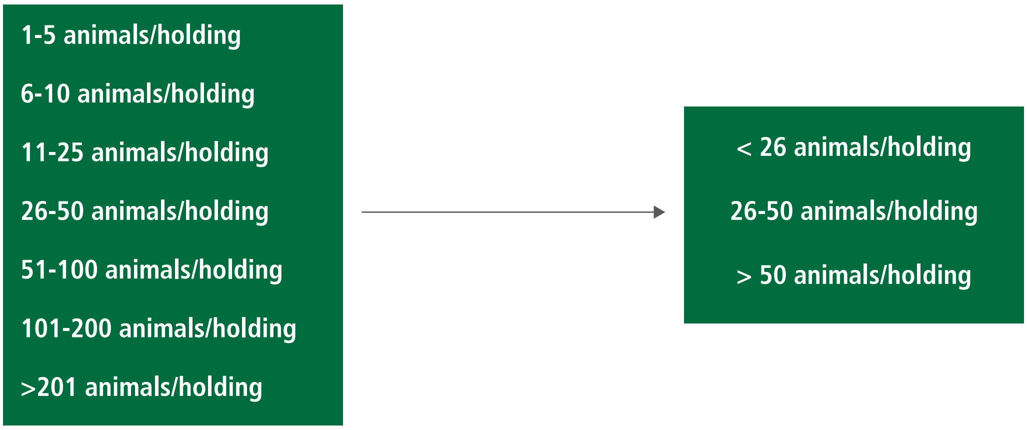
[7] The Turkish Biomass Energy Potential Atlas (BEPA) can be found here: http://bepa.yegm.gov.tr/.

position to invest in a sophisticated manure management system making manure collection and hence its accessibility high.

The size of cattle holding is a good proxy to estimate accessibility of cattle manure in Turkey since bigger farms would enable larger quantities of manure collection at a given time. The Turkish cattle farms are divided into 7 categories ranging from farms that have less than 5 animals per holding to ones that has more than 200 animals. The seven categories were coalesced into 3 broad categories ranging from farm with less than 26 animals to farms that have more than 50 animals.

FIGURE 10.

Animal holding sizes in Turkey



RESULTS

Crop residue assessment results

Step 1: Crop residue production

The quantity of crop residues produced per year is dependent on amount of crop harvested in a given year. In order to maximise the accuracy of the estimation, the average quantity of crop produced per year was calculated based on the annual production quantity between 2010 and 2014. The 5-year average was then used for calculating the amount of residues produced. Table 9 details the 5-year average of production quantity, harvest area and yields for all the crops that were initially selected for the analysis.

TABLE 9.

Average production quantity of crops (2010-2014)

CROP NAME	HARVEST AREA (hectares, AVERAGE, 2010-2014)	PRODUCTION (tonnes, AVERAGE, 2010-2014)	YIELD (AVERAGE, 2010- 2014)
Chestnut	11 797	59 808	0.03
Apricots	112 344	585 974	0.04
Walnut	55 397	191 519	0.03
Almonds	22 741	72 597	0.02
Olive	585 430	1 239 200	0.01
Pistachio	260 462	111 723	0.002
Hazelnut	693 906	530 200	0.001
Sugar beet	296 210	16 409 984	55.40
Rice	108 102	877 756	8.12
Maize	623 423	4 992 753	8.01
Cotton	485 755	2 330 013	4.80
Soybean	32 542	130 501	4.01
Groundnut	31 631	111 883	3.54
Triticale	32 532	108 424	3.33
Rye	132 703	353 671	2.67
Wheat	6 564 181	16 929 800	2.58
Barley	2 609 862	6 657 800	2.55
Oats	89 845	215 737	2.40
Sunflower	633 478	1 438 120	2.27
Chickpea	412 574	498 555	1.21
Tobacco	101 589	68 138	0.67

Note: The yields of crop in light green are tonnes/tree while the yields of all other crops is expressed in tonnes/ha.
Source: TUIK, 2015

Table 10 details the average of production quantity, harvest area and yields for vegetables grown in greenhouses in Turkey.

TABLE 10.

Vegetables produced in greenhouses

CROP	AVERAGE PRODUCTION (Tonnes 2010-2014)	AVERAGE SOWN AREA (hectares 2010-2014)	AVERAGE YIELD (2010-2014)
Artichoke	1.70	23.00	13.53
Broccoli	1.40	24.00	17.14
Cauliflower[8]	0.50	8.00	16.00
Cucumber	37.85	5 116.94	135.18
Eggplant	15.01	1 207.81	80.45
Green Beans	232.86	3 108.17	13.35
Green Peas	16.20	170.00	10.49
Okra	0.30	3.00	10.00
Tomatoes	123.58	5 142.43	41.61

Source: TUIK, 2015

In addition to the crop production values at the national level, crop production was also obtained for all 81 provinces from TUIK (see Section 3 in the Annex for details).

The RCR values specific to the crop and based on the harvesting method were then determined in consultation with the national experts in Turkey. These are presented in Table 11 and are based on the experience and knowledge of the Turkish experts who participated in the technical consultation held in Ankara in 2015. It should be noted that the actual quantity of residues produced in the field or in the processing plant could vary across regions depending on the breed of crop as well as the actual harvesting or processing method used.

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[8] Data for cauliflower for the year 2015 was unavailable.

TABLE 11.

RCR values of crop residues

RESIDUE TO CROP RATIO		
Crop	Residue	Value Used
Cereals		
Barley	Straw	1.1
Wheat	Straw	1.1
Triticale	Straw	1.1
Rye	Straw	1.1
Oats	Straw	1.1
Rice	Straw	1.0
	Husk	0.25
Maize	Stover	1.41
	Cob	0.18
	Husk	0.10
Chickpea	Husk	0.30
Oil seeds		
Soybean	Stalk/straw	0.85
	husk	0.1
Sunflower	Stalk	1.29
	Head	1.17
Groundnut	Husk/shell	0.33
Olive	Kernel	0.50
Fruits		
Almond	Shell	0.43
Walnut	Shell	0.45
Hazelnut	Shell	0.48
	Husk	0.4
Chestnut	Shell	0.2
Pistachio	Shell	0.55
Apricot[9]	Shell/Kernel	-
Sugar crops		
Sugar Beat[10]	tops/leaves	-
Cash Crops		
Cotton	Stalk	7.18
Tobacco	Stalk	1.5

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[9] The RCR could not be established

[10] The RCR could not be established

Step 2: Availability of crop residues

While the production trends of crops provide a general overview of the amount of crop residues produced, it does not define the potential availability or suitability to be used as feedstock to produce bioenergy. In order to identify the potential availability of crop residues for energy utilization, i.e. to define a baseline scenario, a second screening of the initially selected residue-types was conducted. This was done based on the current use of a specific crop residue. The amount of residues that can sustainably be used for energy generation depends on current uses of residues. Residues are spread in the field to prevent soil erosion by wind or water. They can also provide soil nutrients thereby enhancing soil fertility or be used for other purposes such as feed and bedding for livestock etc.

Table 12 below summarizes estimated amounts of residues potentially available for energy production, expressed in percentage of total residues generated. Based on the availability of residues, harvesting and processing practices, some crop residue types initially identified as potential bioenergy feedstock were excluded from the baseline scenario analysis. Physical and technical characteristics of the residues as well as maturity of conversion technologies were also used as screening criteria at this stage.

Most cereals' straw was excluded because wheat straw is in high demand as ruminant feed and bedding and there is a shortage in supply (USDA Foreign Agricultural Service, 2013) that could be covered with straw with similar characteristics, i.e. triticale, oats, rye and barley straw. Rice straw however was included since it is spread in the field and is only partially used as bedding which could be compensated by other cereal straw. Sugar beet tops and leaves are highly nutritious livestock feed and fully used for this purpose. Walnut shells were excluded because of low accessibility and dispersed generation sites. For the most part, the walnuts are grown by households and deshelled by small- to medium-scale bakeries and nut processors, who often use them as fuel. Hazelnut shells are considered high quality wood and used in the furniture industry, e.g. for parquet production. Apricot shells were not assessed due to lack of validated data on the residue to crop ratio. Therefore, it was not possible to evaluate the amount of apricot shells available for energy production in this analysis. Finally, chestnut shells were found unsuitable and unavailable due to the fact that the shell is burnt as part of chestnut deshelling process. Chickpea husk and stalk were included in the numerical analysis, but not elaborated further, due to lack of evidence of market proven energy conversion technologies.

TABLE 12.

Availability of residues for bioenergy production

CROP NAME	RESIDUE NAME	Data obtained from national experts after the technical consultation
		Available for bioenergy (%). Factor used to calculate the potential residue availability
Cereals*		
Barley	Straw	0%
Wheat	Straw	0%
Triticale	Straw	0%
Rye	Straw	0%
Oats	Straw	0%
Rice	Straw	100%
Rice	Husk	100%
Maize	Stover	100%
Maize	Cob	100%
Maize	Husk	50%
Chickpea	Husk	75%
Oilseeds		
Soybean	Stalk/Straw	75%
Soybean	Husk	100%
Sunflower	Stalk	100%
Sunflower	Head	100%
Groundnut	Husk/Shell	30%
Olive	Kernel	100%
Fruits		
Almond	Shell	100%
Walnut	Shell	0%
Hazelnut	Shell	20%
Hazelnut	Husk	80%
Chestnut	Shell	0%
Apricots	Shell/Kernel	NA[11]
Pistachio	Shell	80%
Sugar Crops		
Sugar beat	Tops/Leaves	0%
Cash Crops		
Cotton	Stalk	75%
Tobacco	Stalk	75%

*Based on the technical consultation held in Ankara, cereals' straw was excluded because most of it is in high demand as ruminant feed and bedding. Rice straw, however, was assumed to be fully available for bioenergy production, as it is mostly spread in the field and only a small amount is used as feed and bedding, which can be compensated by other cereal of similar characteristics, i.e. triticale, oats, rye and barley.

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[11] Due to lack of data, the availability could not be estimated.

Table 13 shows the subset of crop residues and the quantity that was deemed available for the production of bioenergy at the national level. It includes 9 crop residues that are collected either at the field or in a processing plant and another 7 that are currently spread in the field.

TABLE 13.

Selected crop residues for further analysis

RESIDUE	TYPE	QUANTITY (t/year)
Sunflower head	Collected	1 675 410
Maize Cob	Collected	898 695
Maize Husk	Collected	249 638
Rice husk	Collected	219 439
Hazelnut Husk	Collected	169 664
Hazelnut shell	Collected	50 369
Pistachio Shell	Collected	49 322
Almond Shell	Collected	30 854
Groundnut Husk	Collected	10 909
Cotton Stalk	Spread	12 547 122
Maize Stalk	Spread	7 039 781
Sunflower stalk	Spread	1 847 984
Rice Straw	Spread	877 756
Soybean Stalk	Spread	83 195
Tabaco Stalk	Spread	76 655
Soybean husk	Spread	13 050

It should be noted that merely looking at the residue availability at the national level might be misleading, as the total amounts do not show the possible level of dispersion of the residues. In fact, although some residues might be available in large amounts at the national level they might be extremely disperse making the actual use non-economical. Therefore, the availability of these residues was also mapped by province. Two distinct sets of results are derived based on the location and physical state of residues (collected vs. spread).

Figure 11 provides a geographical illustration of the amount of collected crop residues potentially available for bioenergy production and the share of each residue type in total across the provinces of Turkey. The collected residues include those residue types that are harvested with the main produce and collected in the fields or in a processing plant. The amounts available are expressed in tonnes per year. Two distinct levels of information are presented in the figure.

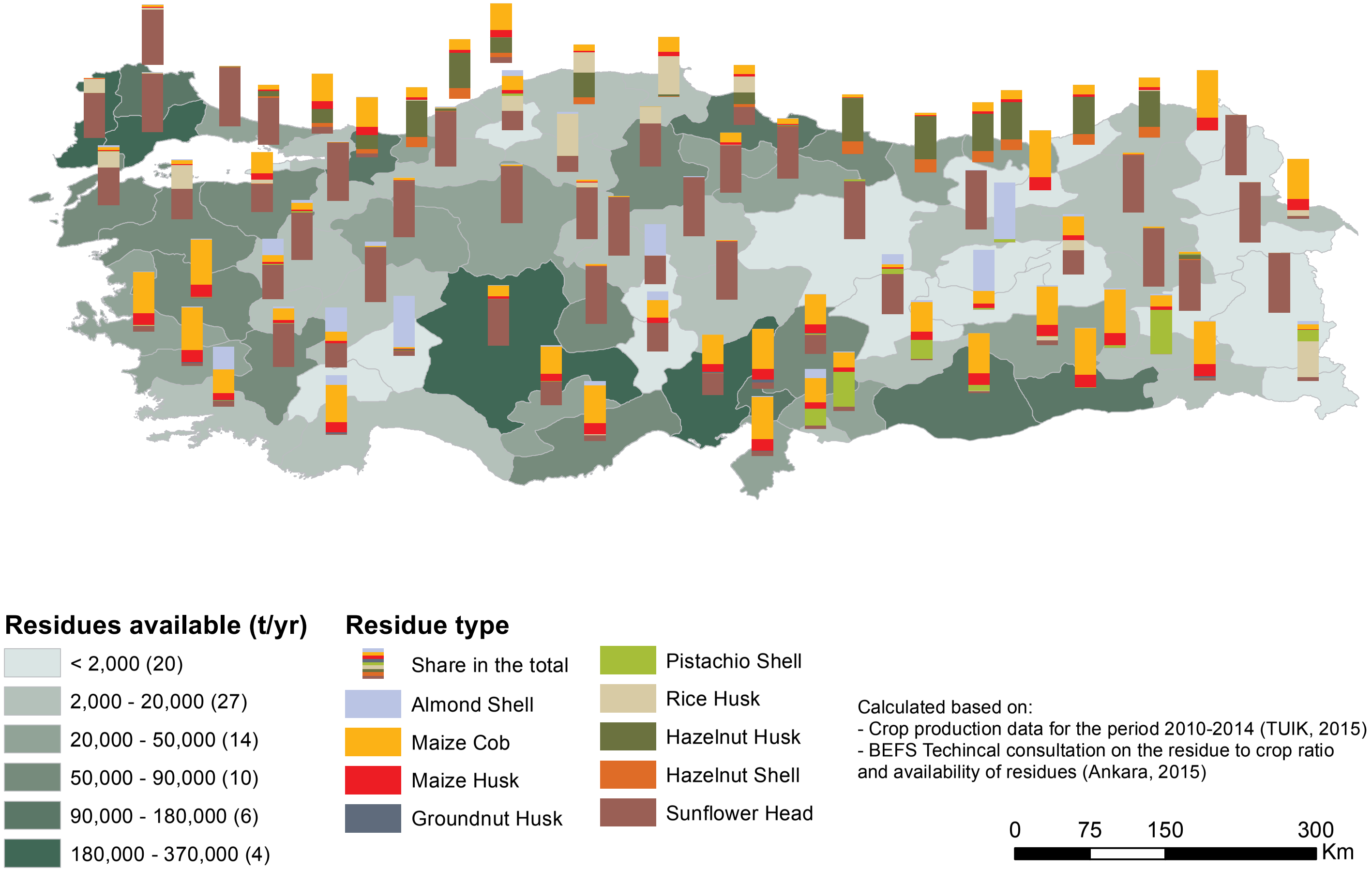
1. The total amount of all residues available: The provinces are represented in different shades of green representing the total amount of residues available. The darker the

shade of green the larger the amount available in a particular province.

2. The share of specific residue type in the total amount of available residues: The bars assigned to the provinces indicate which residue types are available in the respective province and their relative shares (the amounts of residue types are normalized by the total amount of all residues potentially available in the respective province).

FIGURE 11.

Distribution of residues that are collected



Calculated based on:
- Crop production data for the period 2010-2014 (TUIK, 2015)
- BEFS Techincal consultation on the residue to crop ratio and availability of residues (Ankara, 2015)

Almond shell, groundnut husk, maize husk, pistachio shell, rice husk, hazelnut shell and sunflower head are collected at the processing facility while maize cob and hazelnut husk are collected in the field.

In general, the western provinces of Turkey show larger potential availability of crop residues that are collected in the field or in the processing plant than the Eastern provinces. The top 5 provinces where the availability of collected residues is the highest are shown in Table 14.

TABLE 14.

Top 5 provinces in terms of residues collected

PROVINCE	REGION	QUANTITY COLLECTED (t/year)
Edirne	Marmara	368 620
Adana	Mediterranean	307 056
Tekirdag	Marmara	278 414
Konya	Central Anatolia	272 941
Kirklareli	Marmara	172 981

In most of the provinces in the eastern part of the country up to 35 thousand tonnes of residues are generated annually, while in provinces of the Aegean and Mediterranean Regions, as well as in Central and South-eastern Anatolia, considerably more residues are generated.

In most of the provinces of the Aegean and Mediterranean region more than 700 tonnes of almond shells are generated. In addition, in Diyarbakir and Elazig provinces in Eastern Anatolia, 1 169 and 708 tonnes of almond shells are potentially available. On the other side, South-eastern Anatolia is the main region for pistachio production. In Gaziantep, Sanliurfa and Siirt on average more than 1 000 tonnes of pistachio shells are generated annually.

Table 15 shows the top two residues that are collected in the region and corresponding province while Figure 12 shows the estimated amount of residues collected in each region.

TABLE 15.

Most collected by regions and corresponding province

REGION	MOST COLLECTED RESIDUES	TOP RANKING PROVINCE	QUANTITY COLLECTED (t/year)
Aegean	1. Maize Cob	Manisa	52 046.21
	2. Sunflower Head	Denizli	42 606.85
Black Sea	1. Hazelnut Husk	Ordu	41 611.46
	2. Sunflower Head	Ãorum	40 279.41
East and South East Anatolia	1. Maize Cobs	Sanliurfa	99 039.46
	2. Maize Husk	Sanliurfa	27 510.96

REGION	MOST COLLECTED RESIDUES	TOP RANKING PROVINCE	QUANTITY COLLECTED (t/year)
Marmara	1. Sunflower Head	Edirne	276 011.33
	2. Rice Husk	Edirne	88 946.15
Mediterranean	1. Maize Cob	Adana	148 042.84
	2. Sunflower Head	Adana	112 129.62

FIGURE 12.

Quantity of residues collected by regions

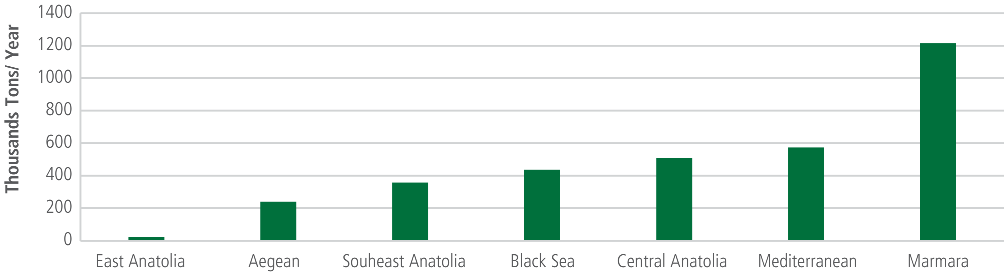


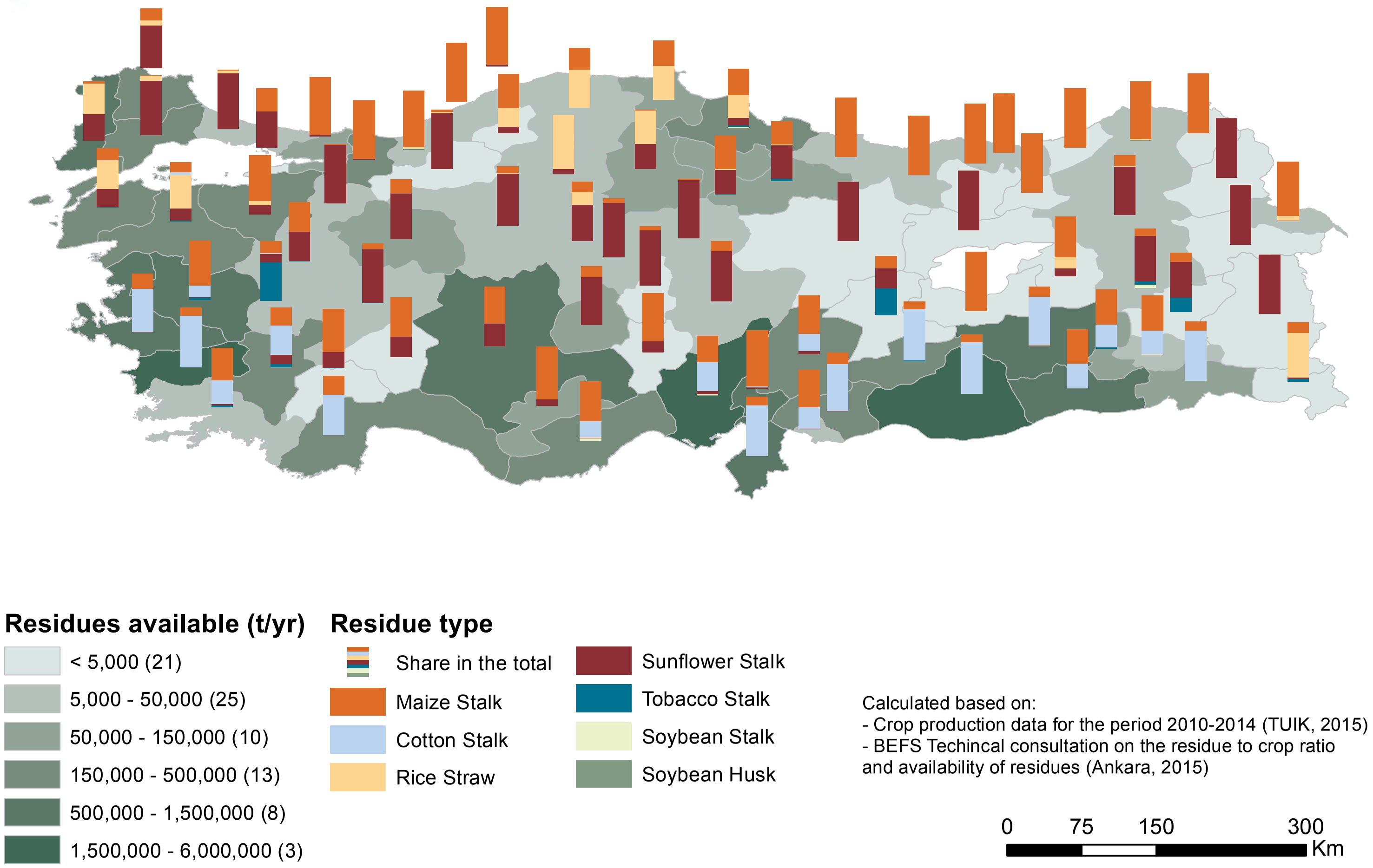
Figure 13 illustrates the availability and composition of residues that are left in the field upon harvest of the respective produce. These include stalks of maize, cotton, tobacco, and sunflower, husk of soybean and rice straw.

As in the case of collected residues, the colour of provinces denotes the total amount of all residue types potentially available. The shades correspond to the amounts expressed in tonnes per year, where the darker the green the larger the amount.

The bars assigned to the provinces represent the available residue types and their relative shares (the amounts are normalized by the total amount of potentially available residues in the field in the respective province).

FIGURE 13.

Distribution of residues that are spread in the field



Calculated based on:
- Crop production data for the period 2010-2014 (TUIK, 2015)
- BEFS Techincal consultation on the residue to crop ratio and availability of residues (Ankara, 2015)

The location of the residues corresponds with the production of the respective crops. Overall, provinces of the western and southern part of Turkey are characterized with high availability of spread in the field residues. Table 16 shows the provinces with the largest amount of spread residues that are available for bioenergy.

TABLE 16.

Top 5 provinces in terms of residues spread in the field

PROVINCE	REGION	TONNES/YEAR
Sanliurfa	Southeast Anatolia	5 912 717
Adana	Mediterranean	2 643 262
Aydin	Aegean	1 661 319
Hatay	Mediterranean	1 403 991
Diyarbakir	Southeast Anatolia	1 203 764

It should be noted that residues with lower heating value that have not been selected for this assessment may also be collected if they are spread in small areas, which would reduce their collection costs. Cotton stalk with a contribution of maize stalks is a dominant residue type in the southern part of the country. More than 80 percent of available residues in the "central belt" of Turkey are attributed to sunflower stalk. Residues spread in the field require collection, storage and possibly pre-treatment prior to their conversion into energy. Therefore, the mobilisation of these residues will require additional effort and possibly higher costs compared to the collected residues.

Table 17 details the top two residues that are spread in the region and corresponding province.

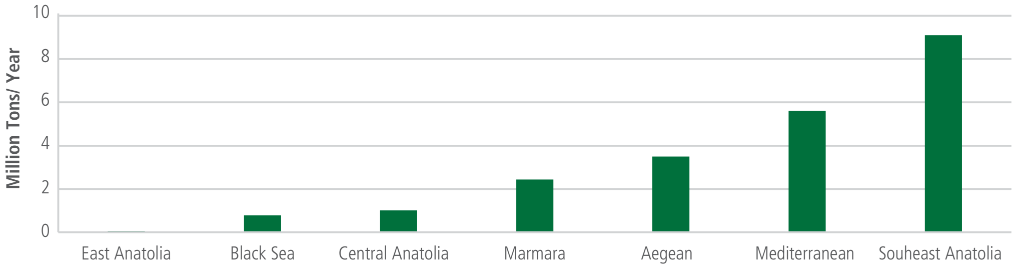
TABLE 17.

Most residues spread in the field by regions and corresponding province

REGION	MOST SPREAD RESIDUES	TOP RANKING PROVINCE	QUANTITY SPREAD (t/year)
Aegean	1. Cotton Stalk	Aydin	1 423 918.93
	2. Maize Stalk	Manisa	407 695.30
Black Sea	1. Maize Stalk	Samsun	137 078.51
	2. Rice Straw	Samsun	120 007.00
East and South East Anatolia	1. Cotton Stalk	Sanliurfa	5 123 235.15
	2. Maize Stalk	Sanliurfa	775 809.07
Marmara	1. Maize Stalk	Sakarya	461 601.29
	2. Erdine	Rice Straw	355 784.60
Mediterranean	1. Cotton Stalk	Adana	1 306 511.93
	2. Maize Stalk	Adana	1 159 668.88

FIGURE 14.

Quantity of residues spread by regions



Step 3: Accessibility of residues potentially available for bioenergy production

It is evident from the above discussion that the potential availability of agricultural residues to produce bioenergy is substantial. However, it should be noted that all the residues that are potentially available to be used as feedstock for bioenergy production might not be accessible. The accessibility of residues depends on various factors including the location of residues (field vs. processing plant). The collection and mobilisation of residues depends on infrastructure such as road density across agricultural land as well as access to specific collection machinery.

Turkey being an upper-middle-income economy already has a well-developed transport infrastructure[12]. Additionally, in 2013 the government allocated USD 26 billion to the infrastructure sector, 30 percent of which was allocated to the transportation sector, followed by education, energy, healthcare, and agriculture (Deloitte, 2013). The Turkish rail network currently covers 10 087 km (World Bank Indicators, 2015) and has an extensive road network (Figure 15).

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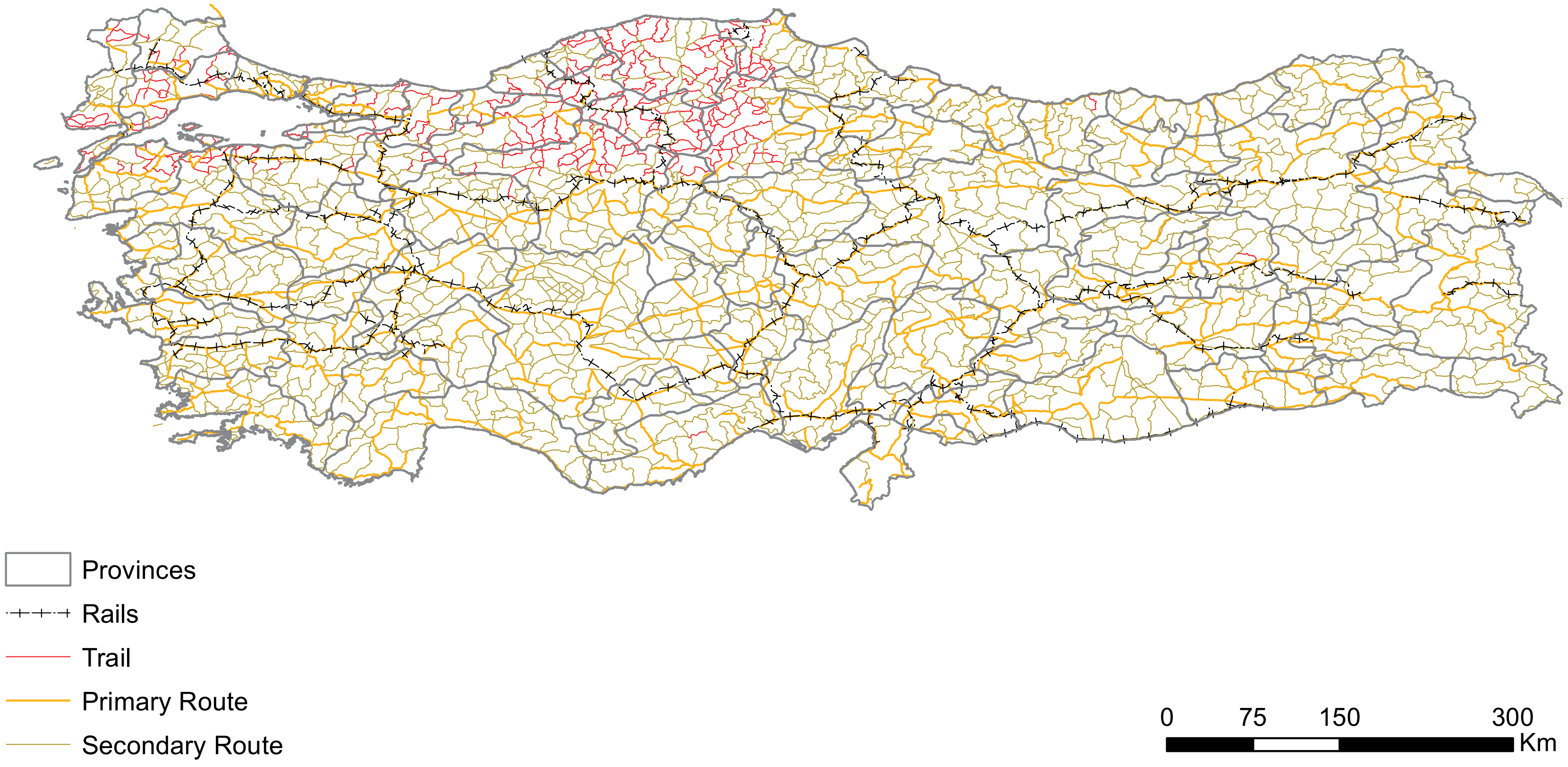
[12] According to the World Bank classification (see http://data.worldbank.org/about/country-and-lending-groups#Upper_middle_income).

FIGURE 15.

Turkish road and rail network



Primary crop residues like cereal straw are generally not collected with the crop and are spread in the field. In many places, they are burnt in the field to quickly prepare the field for the upcoming cropping season. In certain cases, they may be partially collected to be used as livestock bedding or for other local uses. Secondary residues are generated at the agro-processing facility and hence are cheaper and easier to mobilise. There is a fundamental difference in the accessibility of primary residues, which are difficult to mobilise, and secondary, which can easily be mobilised.

The secondary residues that are collected in agro-processing industries are therefore more economical to be used as feedstock for bioenergy generation. Nevertheless, the net availability of primary residues that are spread in the field is substantially larger than the collected residues making them more lucrative for bioenergy production. However, the collection of residues from fields can be costly and depends on the type and availability of harvesting machinery, as different residue types (e.g. straw is easy, but the machinery for collection of cotton stalk may not exist) need different collection methods and machinery.

Additionally, the time of the year when residues are produced is also relevant. For instance, residues that are produced during winter season may require closed/covered storage facilities to prevent rotting and decomposition. The size of agricultural holding is also of importance since in places where agriculture takes place on relatively small fields, primary residues tend to be scattered across many fields making them more difficult to collect, store and mobilise. Additionally, the distribution and size of the agricultural holdings will also have an impact on the location of the bioenergy power plant as well as the transportation cost of the feedstock. Transportation cost is directly associated with the form of feedstock, with pellets, bundles, bags and bales offering more efficiencies than loose feedstock. Transportation may occur in stages, such as from field to aggregator and then aggregator to end-user. Transportation by tractor-trailer is most common, although for longer distances train could be used as the primary transport mechanism.

It is therefore fundamental to understand the accessibility of residues at the site where the assessment is being carried out to accurately predict the technical potential to produce bioenergy production from agricultural residues.

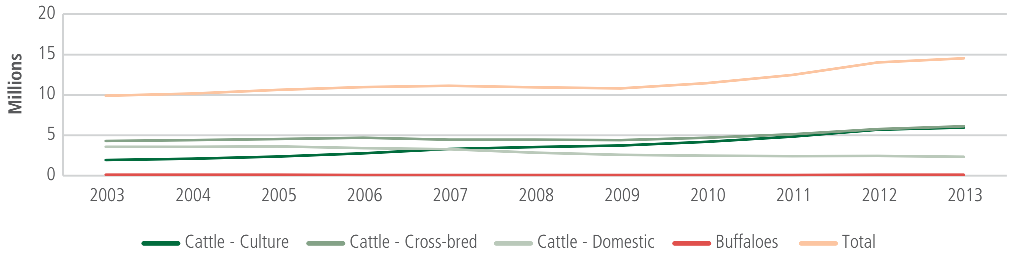
Livestock residue assessment results

Step 1: Production of livestock residues

Cattle are reared in Turkey for meat, milk and hide. Four primary cattle types exist in Turkey: breed cattle, culture cattle, domestic cattle and buffalo. Cow is the most common type of cattle in Turkey, and production represented around 45 percent in the past 10 years (Figure 16).

FIGURE 16.

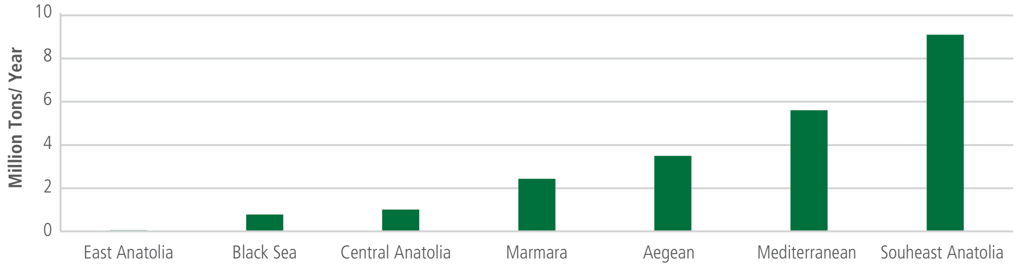
Cattle and buffalo population in Turkey



In addition to cattle, the poultry sector is one of the strongest and most developed food industries in Turkey, and domestic poultry consumption and exports have been increasing over the past few years. Layer population in Turkey, although much smaller than broiler population, has been increasing steadily for the past 10 years (Figure 17). The broiler population peaked between 2005 and 2007 after which it declined but picked up again in 2009-2010.

FIGURE 17.

Chicken population in Turkey



As a first step, the total manure produced in Turkey was estimated. The method estimating the total manure production is based on the number of animals (cattle and poultry) and manure produced per head. By multiplying the amount of heads with the manure per head for specific type of livestock, we can estimate the total amount of manure that is produced.

The quantity of manure produced per animal can vary depending on parameters like the animal breed, age and gender of the animal. Turkish cattle can be divided into 7 subcategories based on their breed, age and gender. Consequently, the value for 'manure per head' for each category was determined through a technical consultation (TAGEM) as well as data available publically through BEPA (Tables 17 and 18).

It should also be noted that where cattle manure is envisaged to be used for biogas production, the physical and chemical properties of manure is critical. The content total solids (TS) and volatile solids (VS) of the manure have a profound impact on potential biogas production. Furthermore, the TS and VS content in manure also depend on the feeding profile of the livestock. For instance, generally cattle and layer manure is chemically more suited for biogas production than buffalo and broiler manure respectively.

TABLE 18.

Manure produced per head

BEFS ANALYSIS IN TURKEY - MANURE PRODUCTION, BASED ON TAGEM (TECHNICAL CONSULTATION) AND BEPA				
	CULTURE CATTLE	BREED CATTLE	DOMESTIC CATTLE	BUFFALO
GENDER/AGE	T/HEAD/YEAR			
Male <12m	9.63	6.93	5.78	7.70
Female <12m	9.63	6.93	5.78	7.70
Young Male 12-24m	11.80	8.50	7.08	9.44
Heifer 12-24m	11.80	8.50	7.08	9.44
Cow	14.75	10.62	8.85	11.80
Bull	18.60	13.39	11.16	14.88
Bullocks	23.87	17.18	14.32	19.09

TABLE 19.

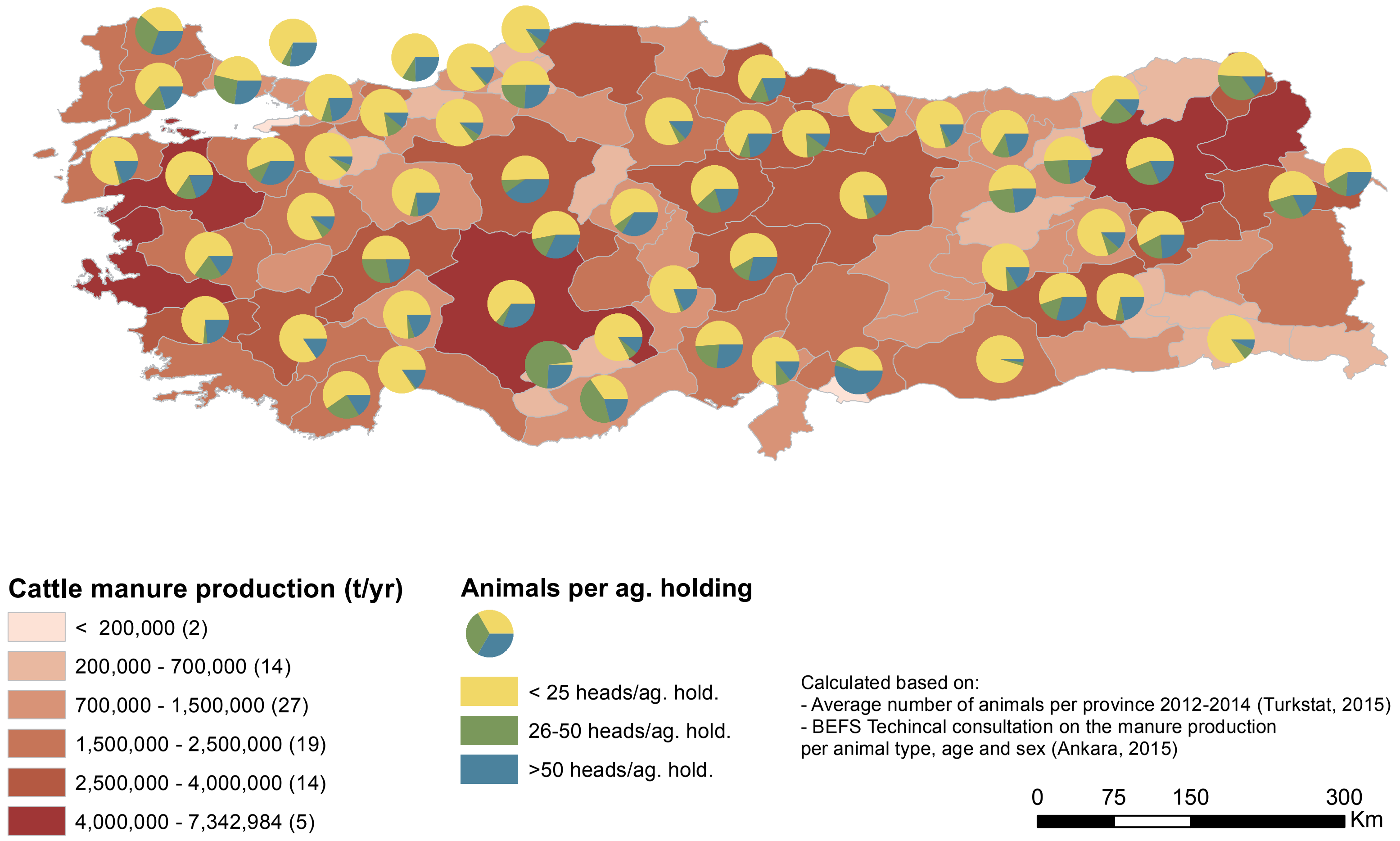
Manure production per head for chicken

TURKEY - BEPA ASSESSMENT	
TYPE	MANURE TONNES/HEAD/YEAR
Boiler	0.02700
Layers	0.05475

Based on the number of animals in Turkey and coefficients for manure produced per head, the total manure produced per year in Turkey was calculated. Figure 18 shows the geographical distribution of manure production in Turkey as well as the distribution of holding sizes across provinces. As in the case of crop residues, the darker blue areas represent higher manure production while the lighter shades of blue represent lower production rate. Additionally, the map also shows the distribution of holding sizes varying from small holdings (less than 25 animals), to medium size farms (having 26 to 50 animals) and large farms (having more than 50 animals).

FIGURE 18.

Production of cattle manure

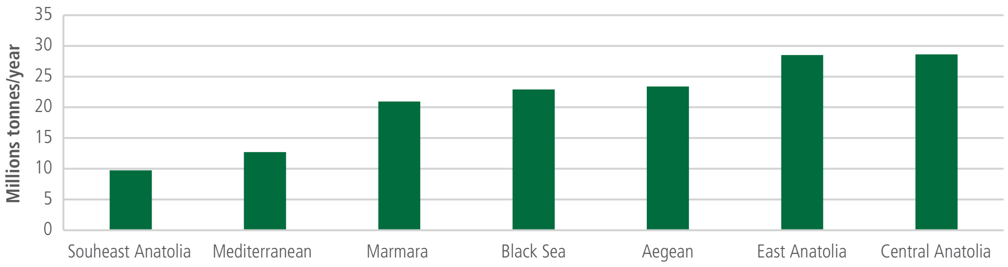


Calculated based on:
- Average number of animals per province 2012-2014 (Turkstat, 2015)
- BEFS Techincal consultation on the manure production per animal type, age and sex (Ankara, 2015)

There seems to be a fairly even distribution of cattle manure availability across the country. However, the East and Central Anatolia regions have the largest share of manure in the country, followed by the Aegean, Black Sea and Marmara regions (Figure 19).

FIGURE 19.

Cattle and buffalo manure produced by region



In terms of provinces, Konya province produces the largest amount of cattle manure followed by Balikesir, Erzurum and Izmir (Figure 20).

FIGURE 20.

Top 5 cattle and buffalo manure producing provinces

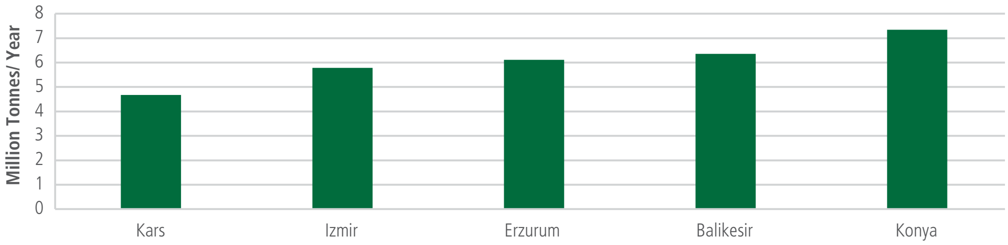
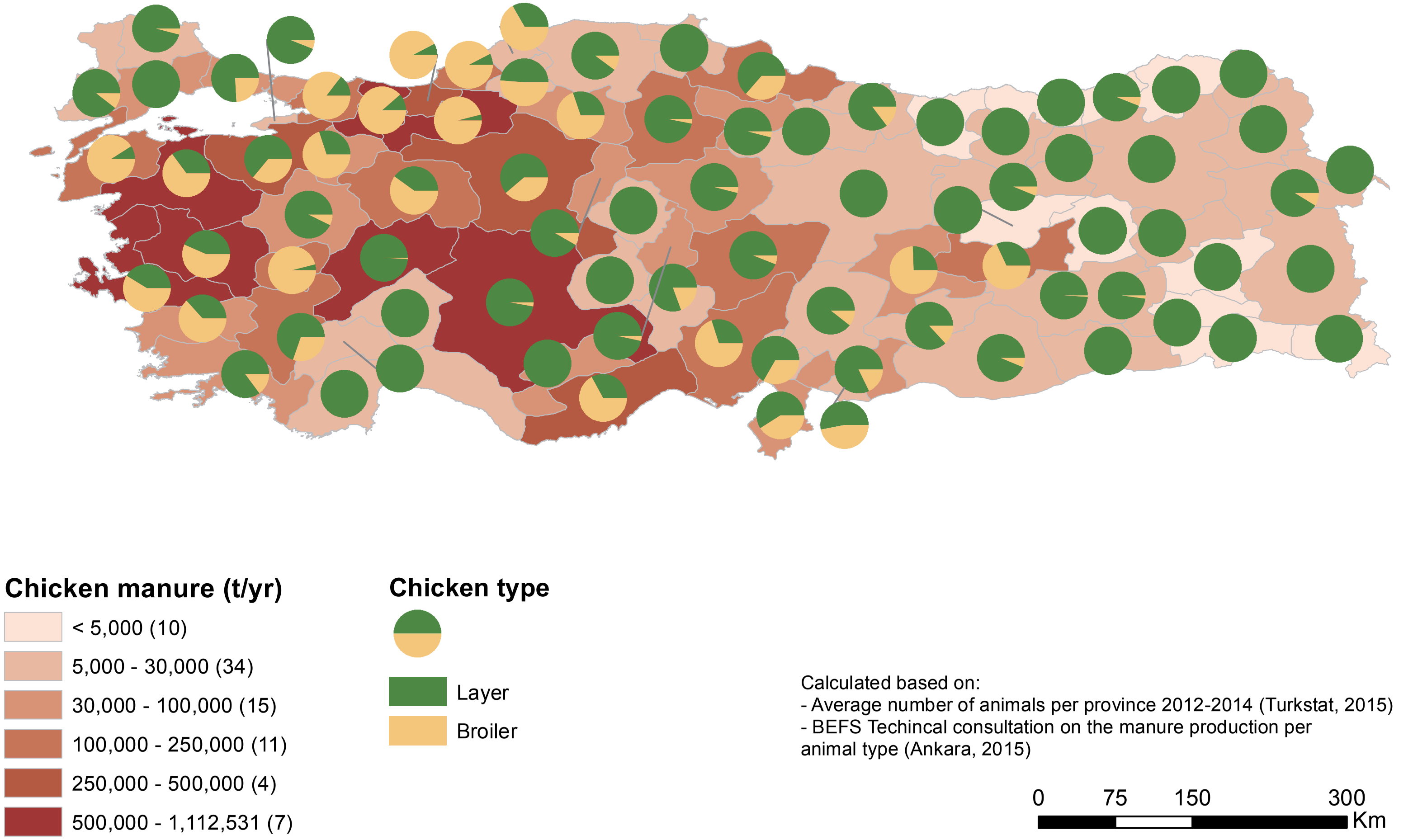


Figure 21 shows the geographical level distribution of chicken manure in Turkey as well as the share of layer and broiler manure in total manure production at the province level. As in the case of cattle manure, the darker blue areas represent higher manure production while the lighter shades of blue represent lower production rates.

FIGURE 21.

Production of chicken manure



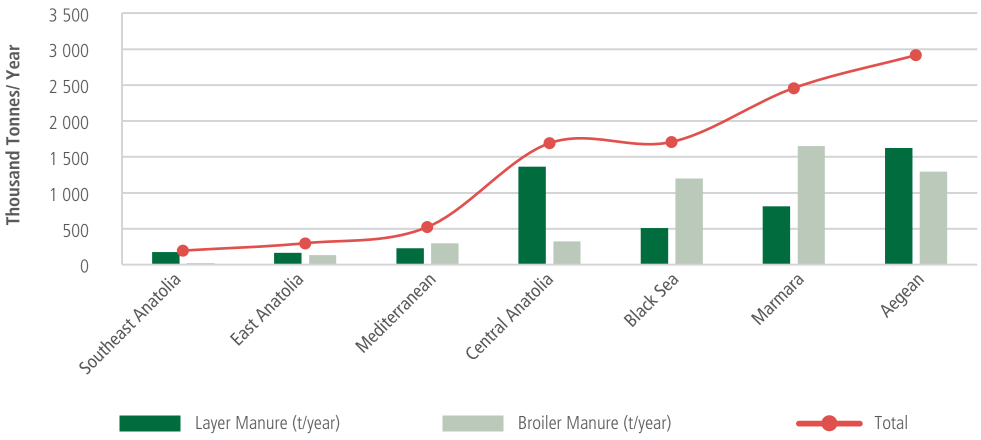
Calculated based on:
- Average number of animals per province 2012-2014 (Turkstat, 2015)
- BEFS Techincal consultation on the manure production per animal type (Ankara, 2015)

Unlike cattle manure, chicken manure does show a geographical concentration in production with most of it concentrated at the western part of the country. The Western region of Aegean is the largest producer of chicken manure followed by Marmara, Black Sea and Central Anatolia.

An important aspect of chicken manure is the distinction between layer and broiler manure. Broiler manure is generally mixed with litter and hence not very suitable for biogas production. Therefore, a general preference is given to layer manure for biogas production. Within the top 4 regions that produce the most chicken manure, Aegean and Central Anatolia have the largest share of layer manure as a percentage of total manure production (Figure 22).

FIGURE 22.

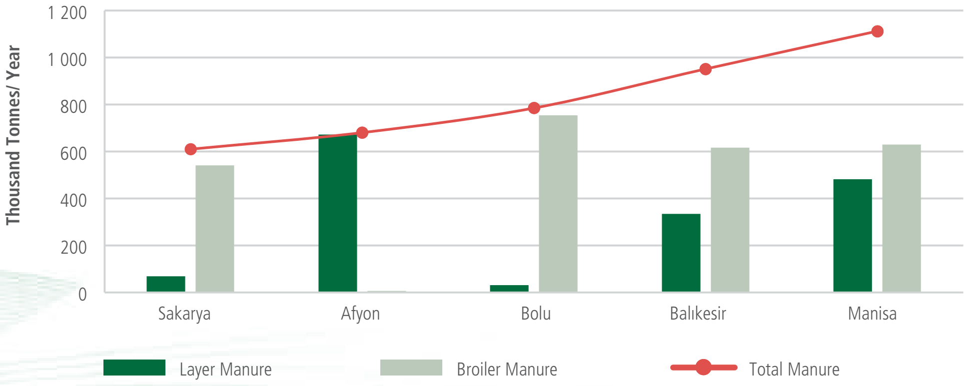
Chicken manure production by region



Similarly at the province level, the western province of Manisa produces the largest amount of chicken manure. However, Afyon and Konya have the largest proportion of layer manure as a percentage of total chicken manure (Figure 23).

FIGURE 23.

Top 5 chicken manure producing provinces



Step 2: Availability of livestock residues

Cattle and poultry manure is an important source of biomass and can be used as organic soil amendment. In some cases, cattle manure is dried into cakes and used as a solid fuel. Therefore, like crop residues, the amount of livestock residues available for bioenergy production would depend on the current uses. However, due to lack of data on the current uses of livestock residues, their availability for bioenergy production could not be estimated. Nevertheless, the geographical distribution of livestock residues calculated in Step 1 can be used as a strong indicator to identify provinces with the largest production of livestock residues. Additionally, a more detailed province specific assessment could be done to further determine the potential availability of these residues. It should also be noted that where manure is being used to produce biogas through anaerobic digestion, the resulting digestive obtained could still be used as a soil amendment.

Step 3: Accessibility of livestock residues

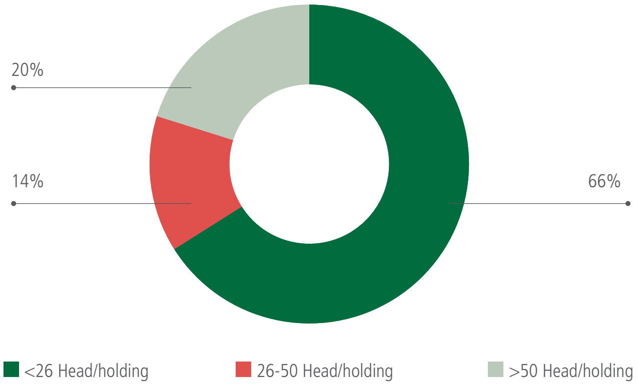
The analysis above finds that there is large potential availability of cattle and chicken manure that can be used to produce bioenergy. However, similar to crop residues, accessing and mobilising livestock manure can be challenging. Therefore, it is essential to examine the accessibility of manure to understand the quantity of manure that can practically be mobilised for energy production. Manure is organic matter used as organic fertilizer in agriculture. Animal manure can be available as a liquid (farm slurry) or in a more solid form. Manure can be collected centrally from stables if intensive livestock rearing systems are applied.

Given the strong variations between east and west Turkey in terms of financial and infrastructural development, as well as agricultural management practices, the accessibility of manure can vary significantly. More specifically, it can be inferred that the accessibility of cattle manure would be much higher in the western provinces where cattle is reared intensively in farms as opposed to the pasture-based extensive cattle rearing system in the east. Intensive cattle rearing systems can reduce the cost of collection while it is almost impossible to collect manure in extensive systems where it is left in pastures.

In addition to livestock production systems, the size of cattle farms is an important parameter that determines the accessibility of cattle manure. Larger farms with more animals allow for the collection of large quantities of manure from the one site. Whereas, smaller farms would have lower quantities of manure and so many farms would need to be visited in order to obtain the same quantity as a large farm. A majority of livestock farms in Turkey have less than 25 animals. At the national level, in provinces that have cattle farms, 20 percent of holdings have more than 50 animals (Figure 24).

FIGURE 24.

Distribution of cattle and buffalo farms by holding size



Source: Calculated based on BEPA

Only 7 provinces have over 30 percent of holdings with more than 50 animals and only one province with more than 50 percent (Figure 25). It can therefore be contended that the accessibility of cattle manure in these 7 provinces will be higher than many other provinces in Turkey.

FIGURE 25.

Provinces where more than 30 percent of the animal holdings are large (>50 heads/holding)

Source: Calculated based on BEPA

In the case of chicken manure however, there is a dearth of data on farm sizes, which makes it difficult to assess the provinces or regions where accessibility could possibly be higher. Nevertheless, it can be argued that as chicken production in Turkey is concentrated in the more developed, western provinces, collecting and mobilising chicken manure could be more cost effective in these provinces. However, more investigation is required to understand whether chicken rearing is free range or enclosed, which affects the collection costs of the manure in addition to the size of chicken holdings.

CONCLUSIONS

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

Two main agricultural residue types were considered:

I. Crop Residues
   This group considered residues: spread in the field, collected in the field, and collected in the processing facility
II. Livestock residues
   These residue group included manure from cattle and chicken manure

In the case of crop residues, the assessment covered production and availability and lists the issues that would need to be addressed in terms of accessibility of residues. In the case of livestock residues, only production of manure was covered, due to lack of data on the current uses of livestock residues.

The analysis covered 16 crop residue types. These residues include 9 crop residues that are collected either at the field or in a processing plant, and another 7 that are currently spread in the field.

In terms of collected residues, the analysis shows that the crop residue types that are mostly available are sunflower head, maize cob, maize husk, rice husk and hazelnut husk. The availability of each of these residue types exceeds 100 000 tonnes per year in Turkey. Of these residues, sunflower head has the highest availability at 1 million tonnes per year in Turkey. 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 having the largest shares in the total.

In terms of residues spread in the field, the analysis shows that 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. Of these three residues, cotton stalk has the highest availability at 12 million tonnes per year in Turkey. Sanliurfa (Southeast Anatolia), Adana (Mediterranean), Aydin (Aegean), Hatay (Mediterranean) and Diyarbakir (Southeast Anatolia) provinces have the largest amount of spread residues in Turkey with cotton stalk and maize stalk having the largest shares in the total.

In general, the western provinces of Turkey show larger potential availability of crop residues that are collected in the field or in the processing plant than the Eastern provinces. However, the total quantity of residues that are spread in the field is considerably larger than the collected residues in Turkey as a whole.

What has to be stressed nevertheless, is 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. What would need to be realistically quantified is the real accessible amount of these residues.

Accessibility is very location specific, and would need to be determined at the local level. The results are an indication of where to focus these efforts further.

In terms of livestock, cattle manure seems to be evenly distributed across provinces. However, the East and Central Anatolia regions have the largest share of manure in the country, followed by the Aegean, Black Sea and Marmara regions.

Konya (Central Anatolia), Balikesir (Marmara), Erzurum (East Anatolia), Izmir (Aegean) and Kars (East Anatolia) provinces have the largest production of cows and buffalo manure with each of them producing more than 4 million tonnes of manure per year. Additionally, the distribution of cattle by holding size was also taken into account based on the data from BEPA. The results indicate that the majority (66 percent) of livestock holdings in Turkey are relatively small holders having less than 26 animals per farm. The 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 half of the farms have more than 50 animals per farm. This is important to consider as, generally, within the larger farms manure is easier to collect and mobilise.

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 of chicken manure, producing around 1 million tonnes each year.

Disaggregating the chicken manure production into layers and broiler it was found that poultry and broiler manure is produced in comparable quantities in Turkey as a whole. Around 4 875 478 tonnes of layer manure is produced in Turkey every year as compared to 4 920 647 tonnes of broiler manure per year.

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 240 000 tonnes per year 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 340 000 tonnes per year.

CHAPTER 3

ENERGY END USE OPTION ASSESSMENT

This section assesses the various energy end use options that can be technically and economically viable in Turkey based on the results of Natural Resource Assessment. A techno-economic and socio-economic analysis is done to evaluate bioenergy potential considering the technical viability, economic profitability, socio-economic impacts and environmental sustainability of the considered bioenergy technologies.

The approach used for this analysis comprises a series of steps, analysing various biomass conditions and operative and economic sensitivity aspects. This allows proposing a series of technical and economic conditions under which certain types of biomass could be more effectively used in certain bioenergy end use options. The end use options covered include briquettes and pellets production, cogeneration of heat and power and biogas production at the industrial scale.

OBJECTIVE OF THE TECHNO-ECONOMIC ANALYSIS

The main objective of the Energy End Use Option Assessment for Turkey was to understand how the biomass potential identified in the Natural Resource Assessment for different provinces can be transformed into potentially profitable and technically feasible bioenergy options. Additionally, considering the combination of feedstock, technologies and profitable production conditions, analyse to what extend Turkish renewable energy targets for biomass could be meet using sustainable bioenergy.

This main objective was fulfilled through the completion of these following specific objectives:

- Identify profitable production conditions for cogeneration of heat and power, briquettes and pellets production from Turkish biomass residues, considering technology options, production schemes, feedstock quality and costs;
- Define competitive production conditions for selected residues, considering the energy pathways and technologies;
- Create a ranking of the most promising feedstock, considering the identified amounts of biomass, profitable production conditions and competitive feedstock conditions; and
- Estimate what would be the participation of bioenergy in Turkish renewable energy targets, considering combined energy production capacity of the different provinces.

DESCRIPTION OF TECHNOLOGIES COVERED

Pelletizing and briquetting

Briquetting and pelletizing are technologies intended to increase the energy density of low bulk density biomass (e.g. densification from 150-200 kg/m^3 to 900 to 1 300 kg/m^3). This operation is technically called *compacting* or *densification*, and helps to convert waste materials into easy to handle fuels (Food and Agriculture Organization of the United Nations 2014). In principle, briquettes and pellets can be generated from a number of sources, including: food processing residues, crop residues, woody residues, charcoal, peat, paper, plastics, etc. (Kozicki 2015).

Briquettes and pellets are used as fuel for heating and cooking applications or as feedstock in other advanced energy generation technologies. Pre-treatment is one of the key step in briquettes and pellets production which is required to have the optimal particle size of 6-8 mm with 10-20 percent powdery component (< 4 mesh) and the moisture content of about 10 percent (Grover and Mishra 1996). However, due to the diverse range of biomass that can be used for briquetting and pelletizing and the particular properties associated with each type (e.g. heating value, size, moisture content, and chemical composition), pre-treatment is typically required to ensure that the biomass conditions are suitable for briquettes and pellets production. In this context, pre-treatment processes may involve drying to remove excess moisture, size reduction (cutting, grinding) and pre-heating biomass (not higher than 300°C) to help loosen fibres in the biomass and to soften its structure which reduces the wear of the screw press (Grover and Mishra 1996, Bhattacharya and Kumar 2005).

While briquettes and pellets are similar in many ways, their main differences are their size and production technologies. Briquettes are usually cylindrical blocks with 50-120 mm diameter. Pellets are smaller cylindrical blocks of 6-12 mm diameter. Production technologies are also different. Thus, briquetting technologies are based on pressure compressing, while pelletizing technologies uses agglomeration. This difference makes that those feedstock not suitable for compression due to their structural and physical properties would be better used through a pelletizing process rather than through a briquetting.

Technologies for briquettes and pellets production can broadly be classified into two main categories: hot press and cold press.

Hot press options uses high-pressure compression of biomass at more than 1 500 bar, increasing the temperature of biomass and consequently melting the lignin contained, while biomass goes passing through a hole at controlled rate. Once biomass leaves the holes pressure is reduced, lignin cools and solidifies binding biomass into a uniform and solid product. Consequently, there is no need to use an external chemical binder avoiding this cost (Hu, Lei *et al.* 2014). However, it should be noted that external energy is required to perform this process at high pressure. The main hot press briquettes machines are piston press (smaller briquettes) and screw press (larger briquettes). Conversely, agglomeration mills or strand granulators are used produce small cylindrical pellets, compressing biomass between rollers. Hot press options are mostly preferred for large scale operations where external energy can be easily acquired (Bialleck and Rein 2011, Fulford and Wheldon 2015).

Cold press options operates at lower pressures requiring low or none external electricity, but using large amounts of binder. These options are used for materials with low amounts of lignin (paper, charcoal, coal, etc.) (Kaliyan and Morey 2010, Fulford and Wheldon 2015) or simply when investment in hot press technologies is not feasible. In cold press technologies particle reduced materials are mixed with a binder (starch, flour, clay, water, etc.), and a press is used to extrude the paste into a mold. It is all possible to shape the briquettes manually. Once wet briquettes are produced these must be dried allowing the binder set and acquire the final form of product. Cold press technologies can also be operated using electricity, nevertheless the common practice is to operate them manually making them the most preferred option for small scale production (Ngusale, Luo *et al.* 2014).

Cogeneration

Cogeneration systems are a thermodynamically efficient way of energy production and can satisfy both heat and power requirements. The surplus electricity produced can then be sold to the electricity public grid. The combined production of mechanical and thermal energy using a simple energy source, such as oil, coal, natural gas or biomass, allows significant cost and energy savings as well as greater operating efficiencies compared to systems designed to produce heat and power separately. The main advantage of a cogeneration system is that less energy is consumed to produce the same amount of energy as compared to separate heat and power production systems (Quintero, Rincón *et al.* 2011, Rincón, Moncada *et al.* 2013, Rincón, Becerra *et al.* 2014).

The current section details the techno-economic analysis of biomass-powered cogeneration plants. In these type of systems, biomass is used as a main fuel source while fossil fuel are only used to supplement energy demands not supplied using biomass in a scheme called co-firing (Kuprianov, Janvijitsakul *et al.* 2006). Steam is a key element in a cogeneration system, which is primarily used as a means to transport energy. Steam has several advantages over other energy carriers such as low toxicity, ease of transportability, high efficiency, high heat capacity, and relatively low costs. Steam holds a significant amount of energy on a unit mass basis that can be extracted as mechanical work through a turbine or as heat for process use. Since most of the heat content of steam is stored as latent heat, large quantities of heat can be transferred efficiently at a constant temperature, which is a useful attribute in many process-heating applications (Prasad 1995, Zheng and Furimsky 2003, Sanjay, Singh *et al.* 2009).

A cogeneration system must be selected according to particular energy requirements of the plant, but taking into account all energy requirements. Some plants use systems that produce more electricity than heating or more heating than electricity. This feature is considered in this work by including three cogeneration technologies:

I. Simple Technology (intended for electricity production only);
II. Semi-Advanced Technology (intended for cogeneration producing more electricity than heat); and

III. Advanced Technology (designed to produce more heat than electricity).

The most commonly used biomass fired cogeneration systems are based on the direct combustion of biomass, such as the biomass steam turbines (Rincón, Becerra *et al.* 2014). In its simplest configuration, the biomass is first dried and then burned on a grate, furnace or boiler, fixed, moving, or fluidized. In the combustion chamber, biomass exothermically reacts with excess air, leading to high reaction rates and high released heat. From an energy generation point of view this reaction allows for the conversion of the chemical energy stored in biomass into usable energy, which is used to generate high-pressure steam. This steam passes through a turbine connected to a generator, producing electricity and low pressure steam using a technology called Back-pressure steam turbine (O'Brien and Bansal 2000). Turbo-generators are also commonly used in this configuration. In case of the main interest of the system is to produce electricity a Condensing Steam Turbine can be used. This equipment is used to condense steam below atmospheric pressure so is possible to extract the maximum amount of energy from it. Formally, this is not a cogeneration system because it only generates electricity, but for the sake of analysis it has been included in this work as a base line. In this sense, simple technology used in this work is featured by condensing steam turbines while semi-advanced by back-pressure steam turbines.

Finally, for advanced technology the latest promising technology for cogeneration is used, this is the Biomass Integrated Gasification Combined Cycle technology (BIGCC). Gasification is a thermo-chemical conversion technology of carbonaceous materials (coal, petroleum coke and biomass), to produce a mixture of gaseous products (CO, $CO_{2,}$ H2O, H2, CH4) known as syngas added to small amounts of char and ash. Gasification temperatures range between 875-1 275 K (Ahmed and Gupta 2012). The gas properties and composition of syngas changes according to the gasification agent used (air, steam, steam-oxygen, oxygen-enriched air), gasification process and biomass properties (Ahmed and Gupta 2012). Syngas is useful for a broader range of applications, including direct burning to produce heat and power or high quality fuels production or chemical products such as methanol (Adapa, Tabil *et al.* 2011, Xu, Ye *et al.* 2011).

The basic elements of a BIGCC system include biomass dryer, gasification chamber, gas turbine, heat steam recovery generator (HRSG) and back-pressure or condensing steam turbines. A gas turbine is a rotator engine that extracts energy from a flow combustion gas. It is able to produce power with an acceptable electrical efficiency, low emission and high reliability. Three main sections compose the gas turbine: compression (air pressure is increased, aimed to improve combustion efficiency), combustion (adiabatic reaction of air and fuel to convert chemical energy to heat) and expansion (obtained pressurized hot gas at high speed passing through a turbine generating mechanical work) (Adapa, Tabil *et al.* 2011, Xu, Ye *et al.* 2011). The HRSG is a high efficiency steam boiler that uses hot gases from a gas turbine or engine to generate steam, in a thermodynamic Rankine Cycle. This system is able to generate steam at different pressure levels. According to process requirements a HSRG system can use single, double or even triple pressure levels (Uddin and Barreto 2007).

Industrial biogas

Biogas is a clean, efficient and renewable fuel produced during anaerobic digestion (AD) of wastewater, organic wastes and biomass. Biological conversion of this organic material is carried out in an oxygen-free environment that generates only biogas and bio-fertilizers as useful by-products. Biogas can be used in simple gas stoves for cooking and in lamps used for lighting in rural areas. It can substitute the use of fuelwood, charcoal or kerosene. Besides, it is a renewable energy source and CO_2 neutral, mainly composed of methane and carbon dioxide. At large scale biogas can be used to generate heat and/or electricity by burning it, as feedstock to produce methanol and chemical feedstock to replace carbon and coal, among other applications.

Biogas industrial assessment comprises a number of technologies for large-scale production and its selection is highly dependent of feedstock's properties, particularly the Total Solids (%). The Total Solids content (TS) is a measure of the suspended and dissolved solids in water. This is also a measure of the substrate availability in a stream to be converted into biogas. Consequently, a feedstock with high total solids content will require a comparatively smaller digester size than a feedstock with low total solids. Moreover, if a feedstock has solid content too high digestion operation would be difficult and total solids will need to be reduced. Then these feedstock need to be mixed with water or a low-solids waste, e.g. wastewater treatment sludge, to dilute the solids content to the operating range (Yang, Xu *et al.* 2015). Anaerobic digestion operation is broadly classified in two different categories according to the TS content: i) low solid content (LS) also called liquid anaerobic digestion, containing between 15-20 percent TS and ii) high solid (HS) or solid-state anaerobic digestion, with a range between 22-40 percent of TS (Monnet 2003, Arsova 2010, Kangle, Kore *et al.* 2012).

TABLE 20.

Type of reactor depending on the TS content

SUBSTRATE	REACTOR OPTIONS
Low total solids content (<15%), e.g. Soluble industrial wastewater, municipal sewage, sewage sludge, aquatic/marine plants, particulate industrial wastes, animal manures	Anaerobic filter, up flow anaerobic sludge blanket reactor (UASB), fluidized bed reactor, continuous stirred tank reactor (CSTR).
High total solids content (>15%), e.g. municipal solid waste, agricultural residues, energy crops	Continuous stirred tank reactor (CSTR), Batch Reactor

Source: Adapted from (Lai, Koppar et al. 2009)

Particularly in this work, four technology options are considered to convert the range of feedstock identified in Natural Resource Assessment that included crop residues, food processing industries residues and livestock residues. At follows the four specific technology options used for biogas production are described:

The Up Flow Anaerobic Sludge Blanket (UASB) is the most used technology for wastewater treatment worldwide (Chan, Chong *et al.* 2009, Abbasi, Tauseef *et al.* 2012, Strezov and Evans 2015). In an UASB the packing material is replaced by a gas collection device. These biodigesters operate in up flow mode, feeding the influent by the bottom, going through dense sludge bed with high microbial activity and a gas-liquid-solid separation device (Chan, Chong *et al.* 2009, Strezov and Evans 2015). This separator device allows separating the liquid effluent, that flows out from the reactor, from the solid sludge, that remains into the de digester, while the biogas is collected (Strezov and Evans 2015). The process is based on the natural immobilisation of the anaerobic bacteria, forming 1-4 nm of diameter dense granules (Wang, Hung *et al.* 2005, Chan, Chong *et al.* 2009).

The Continuously Stirred Tank Reactor (CSTR) is the most common and easy to use biodigester for treating feedstock with high solid concentration and chemical oxygen demand (COD) values higher than 30.000 mg/L (Wang, Hung *et al.* 2005, Chan, Chong *et al.* 2009). Usually the CSTR volumes ranges between 500 to 700 m^3 with an organic loading rate (OLR) ranging from 1-4 kg organic dry matter per m^3 per day (Wang, Hung *et al.* 2005). The CSTR digester is mostly used to stabilize the sludge by converting the biodegradable fractions into biogas (Massoud, George *et al.* 2007). It is usually operated at high temperatures, to increase the process rates. CSTR digestion units are designed in big volumes that make perfect mixing difficult. Mixing is done mechanically or by recycling either flow or the produced biogas. Therefore, the mixing efficiency is an important factor in modelling the solids transport in the reactor and evaluation of the Solids Retention Time (SRT). Materials with very high COD loading rates (30 kg per m^3 per day) can be digested using this technology, reaching an adequate treatment at lower Hydraulic Retention Times (HRT) (even 4 hours) (Wang, Hung *et al.* 2005). Generally, a removal efficiency of 85-95 percent of the COD of the inlet material and a methane content in the produced biogas of 80-95 percent have been reported for this type of digestion (Wang, Hung *et al.* 2005, Chan, Chong *et al.* 2009).

The Plug Flow Reactors (PFR) have a constant volume, but produce biogas at a variable pressure. The size of such digesters varies from 2.4 to 7.5 m^3. PFR digesters consist of a narrow and long tank with an average length to width ratio of 5:1. The inlet and outlet of the digester are located at opposite ends, kept above ground, while the remaining parts of the digester is buried in the ground in an inclined position. As the fresh substrate is added from the inlet, the digestate flows towards the outlet at the other end of the tank. The inclined position makes it possible to separate acidogenesis and methanogenesis longitudinally, thus producing a two-phase system (Rajendran, Aslanzadeh *et al.* 2012). Although the optimal digestion in PFRs is reached at thermophilic conditions, they can be also operated at mesophilic temperatures (Strezov and Evans 2015). Under thermophilic conditions the HRT is usually of 15 to 20 days. In order to avoid temperature fluctuations during the night and to maintain the process temperature, a gable or shed roof is placed on top of the digester to cover it, which acts as an insulation both during day and night (Rajendran, Aslanzadeh *et al.* 2012). The optimal solids concentration of the feed is in the range of 11 percent to 14 percent (Abbasi, Tauseef *et al.* 2012).

The batch reactor the biomass is loaded once and discharged until the end of the process. Because of its simplicity and portability, batch reactors are a good option for treating bio-waste in countries where landfilling is the most common waste management method utilized (Abu-Reesh 2014). Batch reactors function similar to a landfill, but at higher temperatures and with continuous leachate recirculation the biogas yield is between 50 and 100 percent higher than in landfills (Mogal 2013). Another advantage of batch fermentation is the possibility to recover recyclables and other materials after the anaerobic fermentation is completed (Mogal 2013). As the batch digestion is simple and requires less equipment and lower levels of design work, it is typically a cheaper form of digestion (Baskar, Baskar *et al.* 2012). On the other hand, extra safety must be taken to avoid explosions when unloading the reactor after the digestion is complete.

METHODOLOGY OF ANALYSIS

The analysis within the energy end use options' sections generates economic, operating and financial results. The economic set of results includes economic profitability, e.g. production costs and investment requirements. The production costs are compared to market price and/or costs of technologies commonly used in the country for the specific energy option. Operating results include a comparison of the biomass requirement for the different plant scales versus the biomass available as calculated in the biomass availability part of the BEFS approach, number of plants that can potentially be supplied based on the amount of biomass available, and potential households supplied. Financial results illustrate the financial viability of the energy end use option based on net present value. Results are generated both at the single feedstock level and also as a comparison between feedstock.

The assessments for each of the energy pathways was developed through a conceptual design approach based on 'knowledge', e.g. mass and energy balances, physical properties of substances and other physio-chemical parameters (Douglas 1988, Edgar, Himmelblau *et al.* 2001, Smith 2005). Techno-economic coefficients were defined and used to carry out the mass and energy balance calculations, equipment size estimation and energy requirements for the equipment for each energy pathway. These coefficients were obtained through technology specific literature review (Grover and Mishra 1996, Bhattacharya and Kumar 2005, Tumuluru, Wright *et al.* 2010, Posada, Rincón *et al.* 2012 May, Rincón, Hernández *et al.* 2014, Rincón, Moncada *et al.* 2014 January). Representative plant sizes and technologies were selected for the analysis based on the literature review. The standardization of plant sizes and technologies was done to make the assessment globally applicable and their selection was based on a representative range of general plant sizes and technologies used in the global context.

A number of assumptions were considered in order to complete the assessment and adapt it to the Turkish situation. Assumption of briquettes and pellets analysis includes: Four plant sizes were analysed and compared at the same time. Plant sizes are 4 kg/h, 40 kg/h, 400 kg/h, and 4 000 kg/h. The first plant size represents manual operations, while the other three plants sizes represent mechanized operations. It was assumed that manual plants operate under cold press regime (no external energy, use of chemical binder), and mechanized operations are under hot press regime (use of external energy, no chemical binder). Additionally, it was assumed that the owners operate manual plants, so there are no labour or management costs. Moreover, the owner receives the whole revenue from selling the product. Conversely, mechanized plants are formal businesses that hire personnel and have management costs. In the case of cogeneration of heat and power, the three technology options described above were used as variables while plant sizes were calculated directly based on the combination of biomass available, energy potential of feedstock, and operation regime of the plants. Finally, in the biogas case, the BEFS approach considers up to 4 main product options: electricity only, CHP, direct biogas or methane. Given the specific interest of the country, the CHP option was the only option analysed for biogas production from biomass. As a result, two CHP sets of results are presented i) CHP from direct biomass combustion and ii) CHP from biogas.

In all of the result sections, technology variations or plant sizes, along with feedstock availability, feedstock costs and energy potential will be used as variables of analysis. This sums up 4 analysis dimensions and tries to cover a wide spectrum. Local raw material, energy and supplies costs, as well as salaries and prices were collected directed in the country by a local consultant (Yaylacı 2015) and are included in the Annex (Table 71 and 66).

Ranges of analysis

Considering the large number of results obtained in the Natural Resource Assessment section, it was unrealistic to conduct techno-economic analysis for every single result obtained for each feedstock. Therefore, ranges were built based on direct and indirect NR results, which formed the basis for the techno-economic analysis for different points within defined ranges. Thus, instead of conducting multitudes of specific TE analysis for each feedstock, the methodology used for techno-economic analysis allowed identification of specific conditions under which bioenergy pathways (i.e. combination of feedstock and technology) would be promising. Thereafter, only those feedstock were analysed and deemed promising for specific bioenergy pathways that fulfilled the set of specific TE conditions. The ranges were built based on three data sources: i) Direct results of Natural Resource Assessment, ii) Indirect results of Natural Resource Assessment, iii) Energy content of feedstock.

Province level results of the Natural Resource Assessment allowed the identification of minimum and maximum values of feedstock availabilities and residues yields. These are summarized in Table 21.

TABLE 21.

Summarized results of the natural resources potential

CROP-RESIDUE TYPE		AVAILABLE PER YEAR (t/year)		AVAILABLE RESIDUE YIELD (t/ha)		LOCATION	HARVESTING MONTHS
		min	max	min	max		
Almond	Shell	1.00	3 674	0.12	27.33	processing	Sept-Dec
Chickpea	Stalk	1.31	25 769	0.57	2.25	field	July-Aug
Cotton	Stalk	96.93	5 123 235	1.87	30.41	field	Sept-Dec
Groundnut	Husk	1.00	5 767	0.16	0.36	processing	Oct-Dec
Hazelnut	Husk	0.72	52 014	0.09	4.70	field	August
Hazelnut	Shell	0.27	13 004	0.03	1.17	processing	August
Maize	Cob	1.00	148 043	0.25	1.91	field	Aug-Nov
Maize	Husk	1.00	41 123	0.07	0.53	processing	Dec-March
Maize	Stalk	1.00	1 159 669	1.98	14.94	field	Dec-March
Olive	Kernel	2.70	128 334	0.12	9.91	processing	Nov-March
Pistachio	Shell	1.00	17 305	0.13	67.76	processing	Late Aug-Oct.
Rice	Straw	4.00	426 942	8.57	10.16	field	October
Rice	Husk	1.00	88 946	2.14	2.54	processing	Nov-March
Soybean	Stalk	1.00	52 884	0.80	2.74	field	Oct-Dec
Soybean	Husk	1.00	8 296	0.20	0.41	processing	Oct-Dec
Sunflower	Stalk	4.00	348 272	0.84	5.26	field	Aug-Sep
Sunflower	Head	4.00	315 103	0.76	4.76	processing	mid Aug- mid Sept
Tobacco	Stalk	1.13	21 531	0.39	3.11	field	July-Aug

Based on these values, national minimum and maximum values for feedstock availability were found as 1 t/year and 5 123 235 t/year, respectively. However, this initial availability was re-examined taking into account the technical restrictions such as logistic issues (e.g. transport, collection and storage), realistic plant capacities, and desired operation scale. In this sense, a feedstock availability of 1 t/year is a small quantity to supply bioenergy processing plants at the scales interesting for this analysis, and probably would be economically unattractive. Consequently, a minimum value in the range was reset to a larger number depending on the technology option used. For instance, for CHP the minimum feedstock quantity to operate a profitable plant should be 1 000 t/year, while in order to include small-scale briquettes or pellets production minimum quantity should be 10 t/year. On the other hand, limitations in accessibility, collection and transport would make the mobilisation of more than 1 million t of residues to one single bioenergy plant challenging. Therefore, it might be unlikely to collect 5 123 235 t/year. Therefore the maximum quantity was reduced to a more feasible value: 100 000 t/year. The resulting ranges were used in TE analysis.

The Natural Resource Assessment also includes indirect qualitative results such as feedstock location, labour demand, and accessibility of residues. These results along with residues yields, fed into an additional level of analysis where collection costs were calculated.

In bioenergy production from biomass residues, it is assumed that the initial feedstock costs are zero. This is primarily based on the fact that through bioenergy production the residues are in fact being upgraded into a higher value product (energy) and which otherwise would be an environmental problem that would need to be managed. In any case, no matter if, a residue producer is not receiving a direct income for its residues, the bioenergy producer needs to at least take the responsibility for collection and transport of residues to processing plants. In this sense it is possible to state that feedstock cost can be calculated as:

$$\text{Feedstock Cost (USD/t)=Collection Cost(USD/t)+Baling Cost(USD/t)+}$$
$$\text{Transportation Cost (USD/t)+Income feedstock Producer (USD/t)}$$

Equation 1

Where:

Collection Costs: As stated above, regardless of whether or not the crop residues are being offered for free to bioenergy producers, they still need to at least pay for the collection of these feedstock. In this sense, this cost will depend on the feedstock location. Thus, feedstock located at processing plants or collected during harvesting is considered as already collected, resulting in their collection cost to be zero. Feedstock spread in the field after harvesting will have a collection cost for bioenergy producers. Therefore, collection cost accounts for the labour and machinery cost for collecting crop residues in the field. Given the requirements of increasing accessibility and collection rates of crop residues discussed in NR assessment it is assumed that crop collection will be performed under semi-mechanized mode, where manual labour is combined with machinery labour.

Baling Cost: Regardless of the location of feedstock whether a feedstock is spread in the field, collected in the field or collected at the processing plant), they might need to be converted into bales or hays in order to make them easier to handle and transport. Consequently a “baling cost” accounts for the labour and machinery cost for baling production from crop residues.

Transport Cost: Once residues are collected, they need to be transported to the bioenergy processing plant. Transportation cost depends on the transportation distances and unitary transportation costs. First, this parameter will be affected by the current feedstock uses that will determine the collection distance. In other words, for those feedstock with a large number of competitive uses, bioenergy producers will need to travel even further and visit more collection sites, in order to obtain the feedstock required. On the other hand, transportation costs will depend on the state of the roads in the country, fuel prices, type of vehicle and the salaries of the personnel dedicated to drive the vehicle, load and unload the charges. In this analysis, transportation distances are considered as an independent variable, and will be analysed separately from collection and baling costs.

Feedstock Producer Income: This value is assumed as zero in the initial stages of the analysis. However, the last part of each assessment will include what could be the maximum profitable price that might be paid to feedstock producers by bioenergy plants independently if feedstock is collected or sold at market price.

TABLE 22.

Construction of collection cost

CROP-RESIDUE TYPE		AVAILABLE RESIDUE YIELD (t/ha)		LOCATION	COLLECTION STATUS	HARVESTING MONTHS	COLLECTION COST (USD/t)	BALING COST (USD/t)	TOTAL COST (USD/t)
		min	max						
Almond	Shell	0.12	27.33	processing	Collected	September-October	$0	$0	$0
Chickpea	Husk	0.19	0.68	processing	Excluded	July-August	$0	$0	$0
Cotton	Stalk	1.87	30.41	field	spread	Sept-Dec	$11	$12	$24
Groundnut	Husk	0.16	0.36	processing	Collected	Oct-Dec	$0	$0	$0
Hazelnut	Shell	0.03	1.17	processing	Collected	August	$0	$0	$0
Hazelnut	Husk	0.09	4.70	field	Collected	August	$0	$0	$0
Maize	Stalk	1.98	14.94	field	Spread	Dec-March	$263	$13	$276
Maize	Husk	0.07	0.53	processing	Collected	Dec-March	$0	$76	$76
Maize	Cob	0.25	1.91	field	Collected	Aug-Nov	$0	$21	$21
Olive	Kernel	0.12	9.91	processing	Excluded	Nov-March	$0	$0	$0
Pistachio	Shell	0.13	67.76	processing	Collected	Late Aug-October	$0	$0	$0
Rice	Straw	8.57	10.16	field	Spread	October	$91	$13	$104
Rice	Husk	2.14	2.54	processing	Collected	November-March	$0	$19	$19
Soybean	Stalk	0.80	2.74	field	spread	Oct-Dec	$178	$22	$201
Soybean	Husk	0.20	0.41	processing	Collected	Oct-Dec	$0	$0	$0
Sunflower	Stalk	0.84	5.26	field	Spread	Aug-Sep	$105	$0	$105
Sunflower	Head	0.76	4.76	processing	Collected	mid Aug- mid Sept	$0	$0	$0
Tobacco	Stalk	0.39	3.11	field	spread	July-August	$179	$23	$201

Values used for feedstock collection calculation and costs results are summarized in Table 22. The feedstock are classified according to their collection costs. Based on these, a range of collection cost (0 to 300 USD/t) was established (transport excluded). This range was the used in the assessment as feedstock costs.

Residue availability and accessibility are the two main factors effecting bioenergy production.

Availability of residue is discussed in the natural resources section and is based on other competing uses of the residue.

Accessibility of residue is dependent on various parameters including residue yield.

This factor is an indicator of the current uses of residue, then residue with high yields have low current uses and are easier to collect while residues with low yield have many different current uses and are hard to collect. Consequently, it can be expected that producers needs to travel further to collect low yield residues compared to high yield residues.

Considering residues' yields presented in Table 22, the overall minimum residue yield of 0.01 t/ha and overall maximum of 30 t/ha can be identified. As an example of this, a bioenergy project producing 4 000 t/h of briquettes using the maximum residue yield feedstock (30 t/ha) would need to travel a distance of 1.9 km to collect feedstock. Conversely, the same project using a minimum yield feedstock (0.01 t/ha), would need to collect residues at 42.54 km distance to supply the same production capacity.

As explained above, in the worst-case scenario, the minimum collection distance would be around 43 km.

As a rule of thumb, transportation distances for bioenergy projects beyond 25-50 km are uneconomical (Sultana and Kumar 2012). However, for sake of analysis and in order to understand the effect of transportation cost on the unit production cost, a range varying from 3 times the maximum collection distance in the worst case scenario (150 km) was selected as upper boundary. On the other hand, as minimum collection distance a value of 0 km was selected. Consequently, the resulting range of analysis for collection distance was established as 0 km to 150 km.

As for the energy content of feedstock, each type of feedstock will have their own chemical composition in terms of carbon, hydrogen, oxygen, nitrogen and sulphur. Relative quantities of these elements will determine the total potential energy contained in each particular feedstock. Additionally parameters such as moisture, fixed carbon and volatile carbon, will determine how easy it will be to release this potential. The combination of all these parameters is measured by the calorific value of a feedstock or its equivalent property Low Heating Value (LHV). For this specific analysis standard LHV collected from different literature sources were used (Lindley and Smith 1988, ECN 2012, Desideri and Fantozzi 2013, Đurić, Brankov *et al.* 2014).

TABLE 23.

Energy potential for crop residues

CROP	RESIDUE	ENERGY POTENTIAL LHV (MJ/kg)
Hazelnut	Shell	19.9
Groundnut	Husk	18.6
Cotton	Stalk	18.1
Maize	Cob	17.7
Pistachio	Shell	17.7
Maize	Husk	17.4
Hazelnut	Husk	17.0
Almond	Shell	17.0
Olive	Kernel	16.7
Soybean	Stalk	16.7
Maize	Stalk	16.4
Tobacco	Stalk	16.2
Wheat	Straw	15.9
Soybean	Husk	15.5
Rice	Straw	14.9

CROP	RESIDUE	ENERGY POTENTIAL
		LHV (MJ/kg)
Sunflower	Head	14.5
Chickpea	Stalk	14.3
Cotton	Husk	14.2
Sunflower	Stalk	13.6
Rice	Husk	13.5
Apricot	Shell	13.2
Apricot	Kernel	13.2

In the TE analysis, LHV is used as an indicator of the "energy quality" of each type of feedstock (Table 23). Then bioenergy obtained from highly energetic feedstock would be more valuable than others with low energetic feedstock. For example, bioenergy products obtained from hazelnut shells will be more valuable than bioenergy products from apricot kernels, independent of the cost or availability. In the TE assessment a range from 10 MJ/kg to 20 MJ/kg was used as the energy potential of feedstock.

In summary, the following values were used as ranges of analysis within the TE assessment helping to cover the main features of all feedstock available (Table 24).

TABLE 24.

Range analysis summary

END USE OPTION	MIN FEEDSTOCK YIELD (t/ha)	MAX FEEDSTOCK YIELD (t/ha)	MIN FEEDSTOCK AVAILABLE (t/year)	MAX FEEDSTOCK AVAILABLE (t/year)	MIN COL. COST (USD/t)	MAX COL. COST (USD/t)	MIN ENERGY POTENTIAL (MJ/kg)	MAX ENERGY POTENTIAL (MJ/kg)
Briquettes/Pellets	0.03	15	10	100 000	$ 0	$ 300	10	20
Cogeneration (CHP)	0.03	15	1	100 000	$ 0	$ 300	10	20

Note: The exchange rate used was 1 USD = 2.47 TL.

RESULTS

Briquettes and pellets results

It is imperative to understand the effect of transport cost and distances on production costs. This analysis was performed based on three production costs corresponding to 4 plant sizes (i.e. 4 kg/h, 40 kg/h, 400 kg/h, and 4 000 kg/h) for the defined collection range (0 to 150 km). The range of collection costs was also taken into account in this analysis. Specifically three collection costs were selected (USD 0, USD 150 and USD 300), representing three groups of feedstock: Low Cost, Average Cost and High Cost.

FIGURE 26.

Comparison of Briquettes: Production costs vs. transportation distance and different cost of feedstock

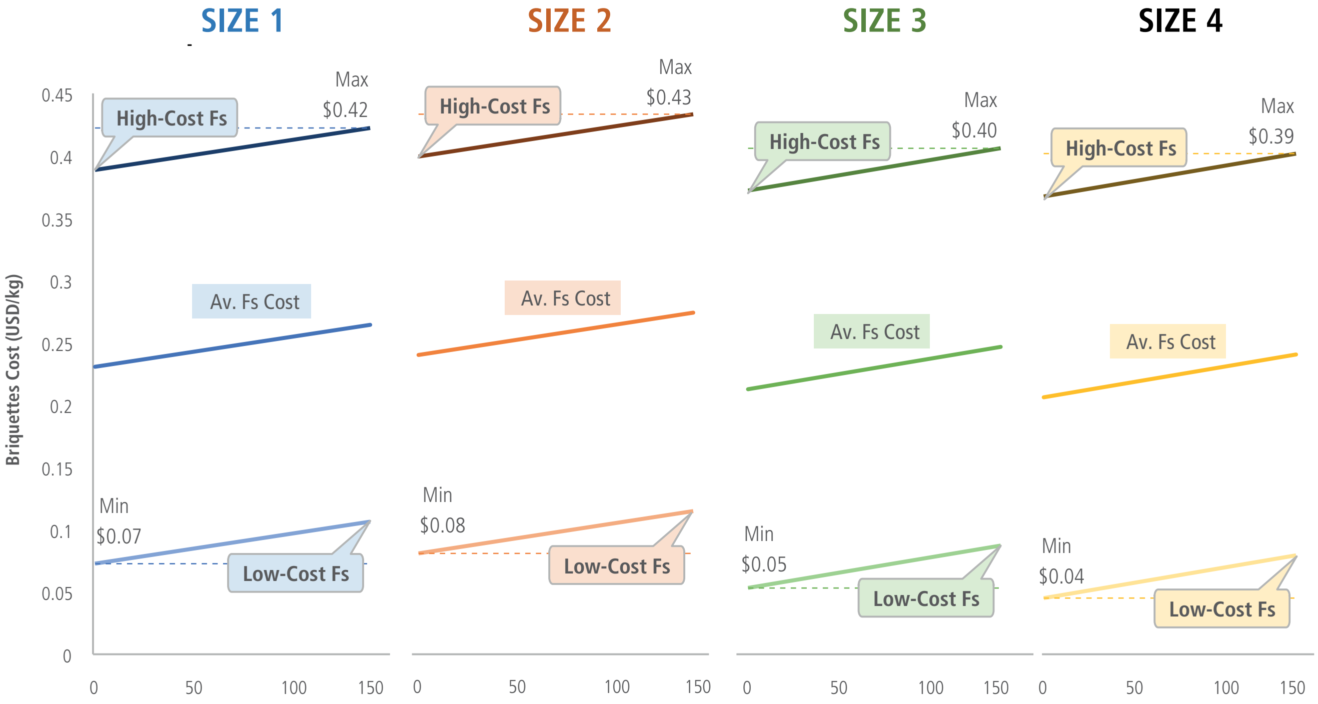


FIGURE 27.

Comparison of Pellets: Production costs vs. transportation distance and different cost of feedstock

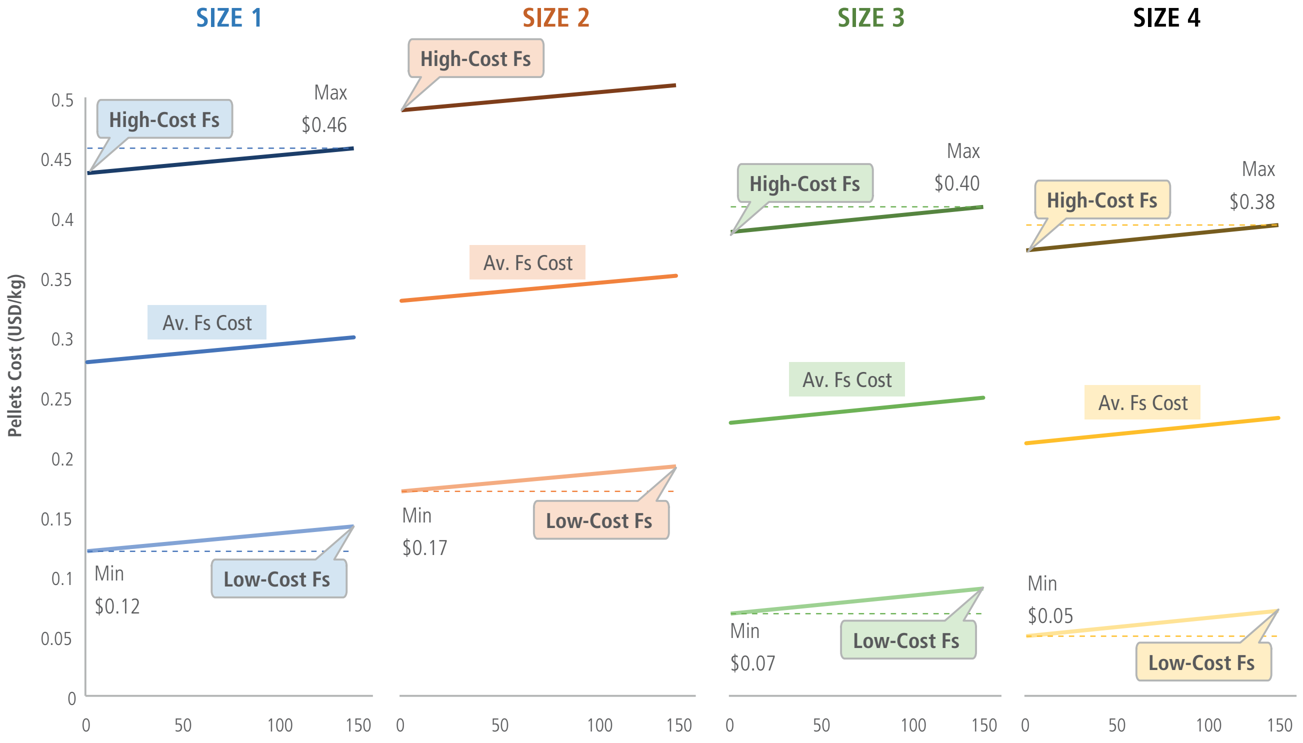


Figure 26 and Figure 27, show unit production cost for 4 plants sizes analysed for the production of briquettes and pellets. It is evident that the main factor affecting the production costs is the feedstock cost. It is also evident that its effect is stronger than transport cost for all plant sizes and both for pellets and briquettes industries, supporting the results obtained in Sultana *et al*. 2010 (Sultana, Kumar *et al*. 2010).

Sultana *et al*. (2010) calculated for large-scale straw pellets factories (around 500 000 kg/h) in Canada, production costs of 0.0132 USD/kg for straw pellets, 0.0140 USD/kg for wood pellets, 0.0146 USD/kg for switch grass pellets and 0.0156 USD/kg for alfalfa pellets (Sultana and Kumar 2012).

Mani *et al*. 2006 report values ranging 0.04-0.05 USD/kg for sawdust pellets in plants ranging (6 000 – 10 000 t/h) (Mani, Sokhansanj *et al*. 2006).

For small-scale production Stolarski *et al* 2013 reported values of 0.074 - 0.153 USD/kg (Stolarski, Szczukowski *et al*. 2013). Given the low cost assumed by the above authors for feedstock collection results can be directly compared against results obtained for low cost and average cost feedstock option. In this sense results obtained for Turkey can be considered accurate enough at this level of analysis, and can be also stated that results obtained for high costs feedstock calculated using the same method can be considered as a meaningful extrapolation of the other two results.

The other variable of analysis considered in Figure 26 and Figure 27 is transport cost. Results obtained for production costs were calculated using a proxy for current transport cost of biomass in Turkey (0.133 USD/t) (Yaylacı 2015). This value is close to 0.156 USD/t/km reported in Malaysia, 0.206 USD/t/km in Thailand, 0.190 USD/t/km in Spain, 0.30 USD/t/km in China, but cheaper than Japan 2.240 USD/t/km (Delivand, Barz *et al*. 2011, Shafie, Masjuki *et al*. 2014, Ng, Promentilla *et al*. 2015).

Consequently, it can be stated that current transport cost is a good indicator of how transport infrastructure, economies of scale, state of the roads and efficiency transport sector makes Turkey competitive compared to other countries and offers good opportunities to develop the bioenergy sector. Thus, differences in unit production costs results showed also how these are mainly affected by feedstock cost. The difference in results obtained for high costs feedstock and low cost feedstock was 0.34 USD/kg average, while differences due to transport cost was 0.02 USD/kg between 0 km and 150 km distances. Thus, it can be stated that transport effect won't be influential enough to be considered as one of variables of analysis, then it will be set as 20 km for collection and distribution to market.

In order to understand the potential competitiveness of the briquettes and pellets industries in Turkey is necessary to compare production cost to market price of briquettes and pellets. Average market price of briquettes in 2015 was 0.14 USD/kg and 0.18 USD/kg for pellets (Yaylacı 2015). Nonetheless, the potential use of pellets and briquettes as fuel is primarily associated with their value as fuels in terms of how much energy they can produce.

Briquetting and pelletizing are operations intended to increase biomass density in order to make it easier to transport and use biomass as fuel. Nevertheless, fuel properties of briquettes and pellets are still the same as the biomass that they are made of. Therefore, briquettes and pellets made of feedstock with higher heating value will be more appealing than those made from low heating values. In general terms authors agreed that clients would accept to pay more for the highest-quality briquettes and pellets, because these burn more slowly and evenly (Eriksson and Prior 1990, Fulford and Wheldon 2015). Other important aspects affecting the future of briquettes and pellets as fuel is their potential as replacements for current fuels consumed in the country for heating and cooking that might convenient to replace by renewable energy, due to their effect on deforestation (e.g. fuelwood) or dependence on fossil fuels (e.g. kerosene, LPG, coal, etc.). Considering this next level, the comparison of production cost should be performed versus the current prices of these products in the country, but also with the prices of fuel in potential markets that might replace fossil fuels in the future in order to understand whether there exists any economic incentives for this replacement. As a result the Energy Potential was included as an additional variable changing the unit basis from mass (kg of product) to energy (GJ) (Figure 28 and Figure 29).

FIGURE 28.

Comparison of Briquettes: Production costs vs. energy potential and different cost of feedstock

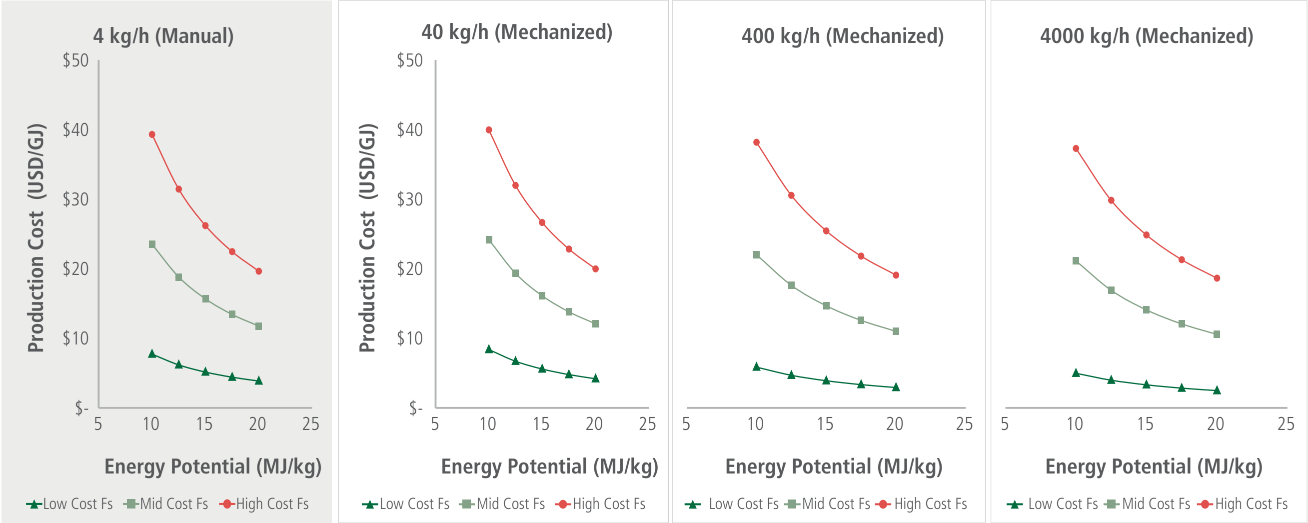
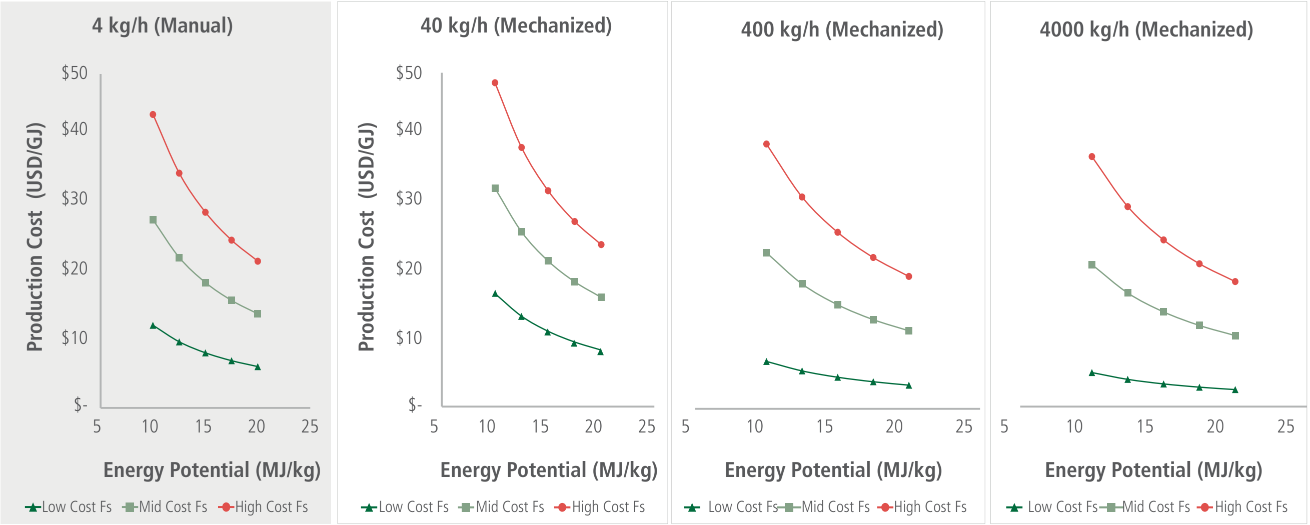


FIGURE 29.

Comparison of Pellets: Production costs vs. energy potential and different cost of feedstock



It can be seen how for all plant sizes considered, still the most important effect on production costs is feedstock cost. Nevertheless, the energy potential of feedstock has a direct impact on production costs reflected in a lower unit production cost of high-energy potential feedstock compared to low energy feedstock. This will be a direct indicator of the market value of these products. Thus, briquettes and pellets produced from high-energy potential feedstock will be more valuable and might receive a higher market value. In order to asses this, it was used an indicator of business profitability with a time-value of money such as Net Present Value (NPV) (see equation 2) (El-Halwagi 2012).

$$NPV= \sum_{i=0}^{n} \frac{Annual\ Cash\ Flows}{(1+i)^{n}}$$

Equation 2

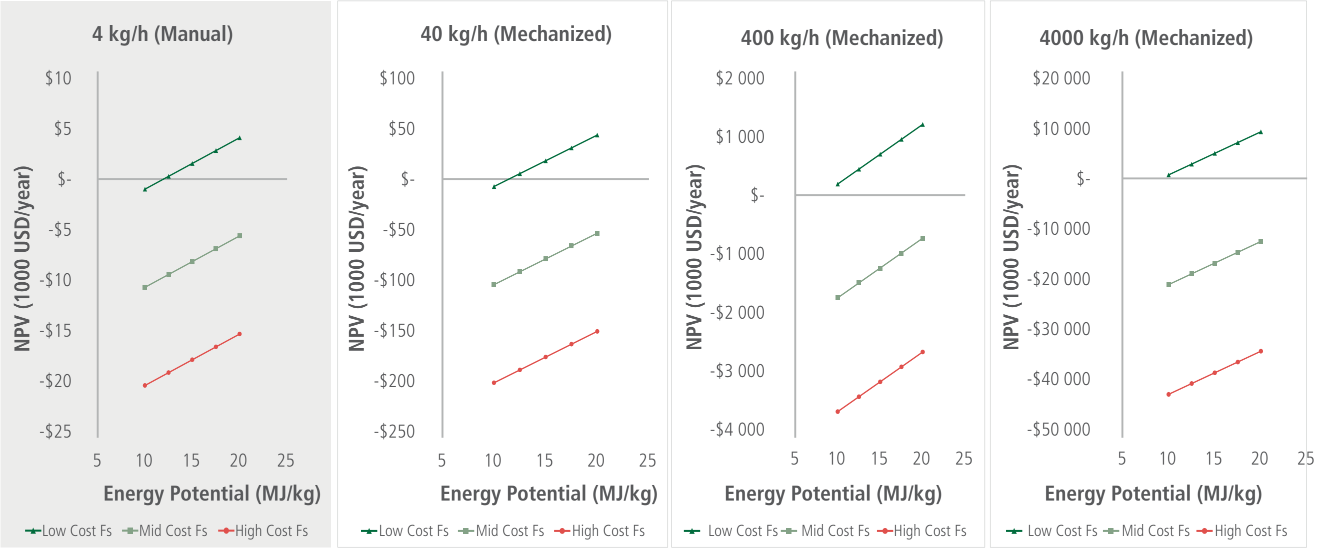
The NPV equation presents the cumulative value (revenues–expenses) adjusted to the reference time, where the term (1+i)n is the discount factor, and is called the discount rate (El-Halwagi 2012). For these kinds of bioenergy projects an acceptable discount rate range is 9-11 percent (Committee on Climate Change, 2011). Annual Cash Flows were calculated based on annual revenues and productions costs, using as reference prices for briquettes and pellets 0.14 USD/kg briquette and 0.18 USD/kg pellets, identified for black sea region (Figure 30 and Figure 31).

Considering the above information the potential economic performance in the market for briquettes and pellets, the net present value was calculated, in order to understand what would be the best conditions for developing this industry in Turkey, from an economic point of view.

Results for briquettes showed how only production based on low cost feedstock (i.e. no collection cost) would be profitable over time, given that these results (green lines) showed positive NPV over the range of energy potentials analysed. As a result, it is possible to state that only a very specific set of feedstock with no collection costs would be possible to be used as feedstock for briquette production to be economically feasible regardless of availability. However, this situation might not be sustainable over time because it is highly unlikely that crop producers would readily give their residues away for free once they realize somebody is generating an income from it. Consequently, under the reference price of briquettes (0.14 USD/kg briquette) only projects owned by feedstock owners themselves would be economically sustainable (Figure 30).

FIGURE 30.

Comparison of NPV of briquettes vs. energy potential and the different cost of feedstock



The pellets results allowed a better economic performance over time for larger plant sizes than briquettes. Small-scale operations (4 kg/h and 40 kg/h) would be hardly profitable. These results show how, in spite of the difference between the reference prices of briquettes (0.14 USD/kg briquettes) and pellets (0.18 USD/kg pellets), the comparatively higher production costs of pellets at a lower scale that drive the differences in economic performance. An example of this can be seen in Figure 31 where the annualized production costs of briquettes and pellets were compared for the low feedstock cost case. As can be seen, small scales production costs are almost 50 percent higher in the case of pellets than for briquettes, probably because of the high influence that fixed capital investment has on small-scale operations.

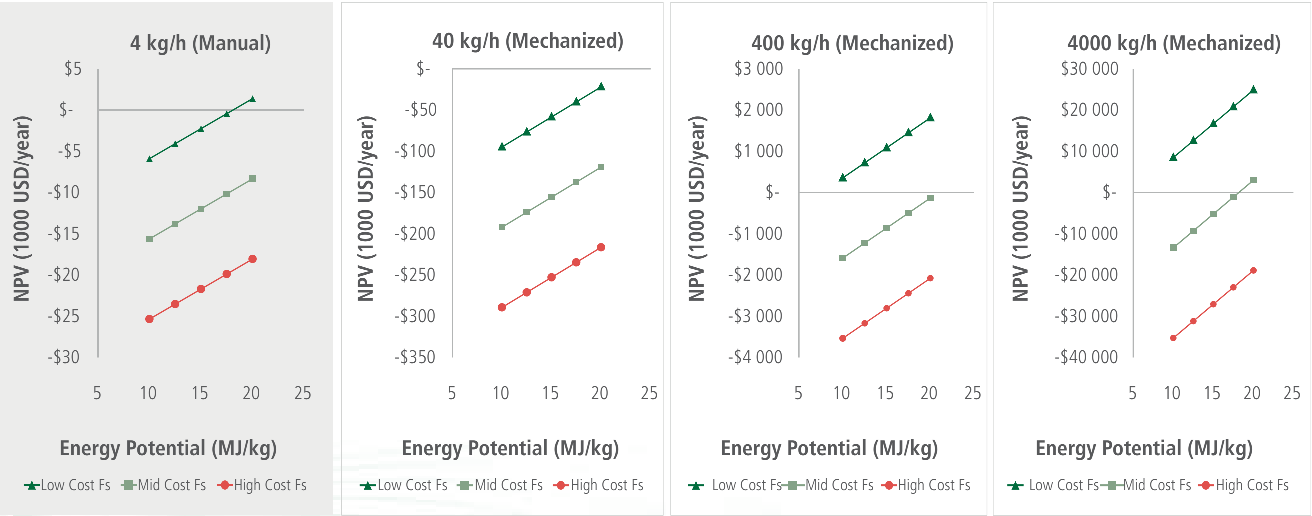
FIGURE 31.

Comparison annualized cost briquettes and pellets for low cost feedstock

Despite the poor economic performance of small-scale operations, it is interesting to see how larger scales (400 kg/h and 4 000 kg/h), where production costs are closer, the effect of price differences plays a major role increasing the projected NPV result. This result brings in the possibility of including mid cost feedstock (i.e. feedstock cost = 150 USD/t), increasing the number of feedstock that it could be possible to consider as business options, allowing profitable ventures not only for feedstock owners, but also for producers paying up 150 USD/t for residues.

FIGURE 32.

Comparison of NPV of pellets vs. energy potential and different cost of feedstock



The maximum price that might be paid by briquettes and pellets producers was estimated for different energy potentials.

TABLE 25.

Maximum feedstock price for briquettes and pellets under current reference prices

LHV	BRIQUETTES	PELLETS
(MJ/kg)	MAX PRICE	MAX PRICE
>13	$0	$0
>15	$35	$0
>17	$75	$75
>19	$75	$150

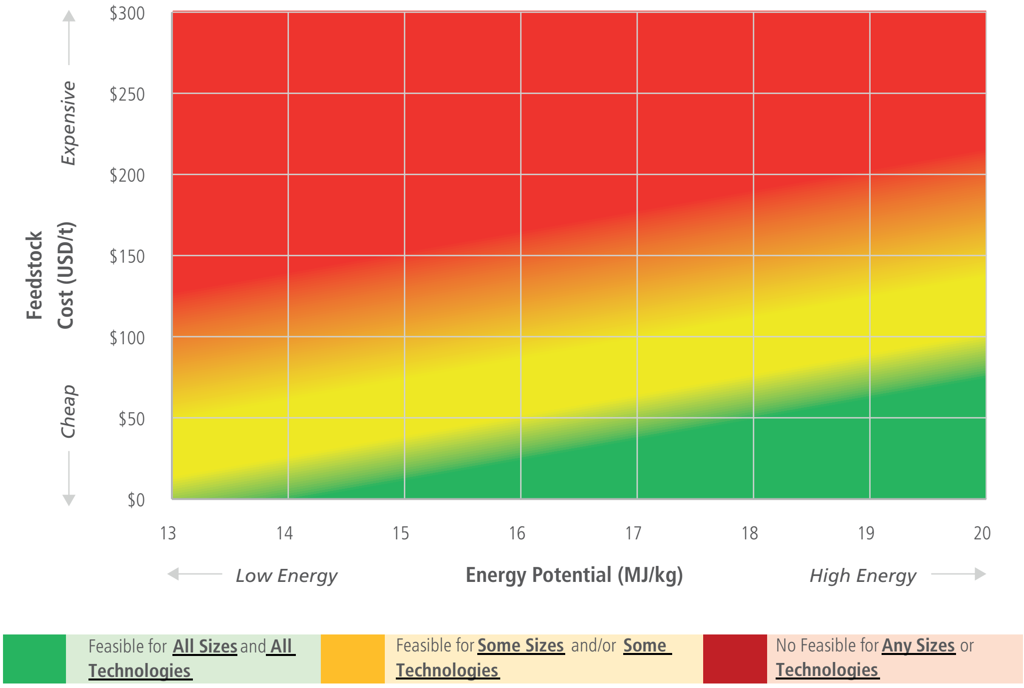
Note: The exchange rate used was 1 USD = 2.47 TL.

Table 25 shows how under current reference prices the minimum feedstock quality that should be used in Turkey is 15 MJ/kg for briquettes and 17 MJ/kg for pellets. However, in the case of the most valuable feedstock and considering the potential higher revenue that might be obtained by pellets produced (higher pellets price) makes this option more competitive and flexible for higher energy potential feedstock allowing for the payment of a comparatively larger amount.

Once the above results were obtained, the next step required an analysis on which feedstock might be preferable for briquette and pellet production. At this point it is necessary to introduce the **Profitability Zones Maps**. This concept was created in order to make easier the use of the profitable production criteria. In these maps feedstock are located according to their energy potential and feedstock cost in an X-Y chart. They are comprised of three zones demarked with different colours and defined according to the maximum prices identified for each scenario. The green zone has those feedstock with energy potential and/or feedstock cost that fulfil profitable production criteria for all technology options. The yellow zone comprises of feedstock that meet partially profitable production criteria, either for certain plant sizes or technologies. Finally, in the red zone are feedstock that do not meet these requirements at all. Profitability Zones Maps are also useful to identify the maximum price that might paid for a feedstock under a given set of production conditions (Figure 33). As an example, an energy potential of 17 MJ/kg can be profitable up to 50 USD/t, using any cogeneration technology. However, if the feedstock price were increased to 75 USD/t, this option would only be profitable using certain technologies and plant sizes. Finally, if the price of this same feedstock were increased to 120 USD/t, production would not be at all profitable. These maps also allow for the comparison of feedstock options with similar prices but different energy potentials in order to decide what option would allow a more profitable and stable production.

FIGURE 33.

Example of profitability zones map



In order to populate profitability zones maps, the first step was to select, among the total list of crop residues available, which residues have been technically used for briquette and pellet production using information available in scientific literature (Demirbaş 1999, Musa 2007, Oladeji 2010, Monlau, Barakat *et al.* 2012, Rajkumar and Venkatachalam 2013, Tumuluru, Tabil *et al.* 2015). The list of residues as well as energy potentials and feedstock costs is summarized in Table 26.

TABLE 26.

Summary of feedstock selected for briquettes and pellets production

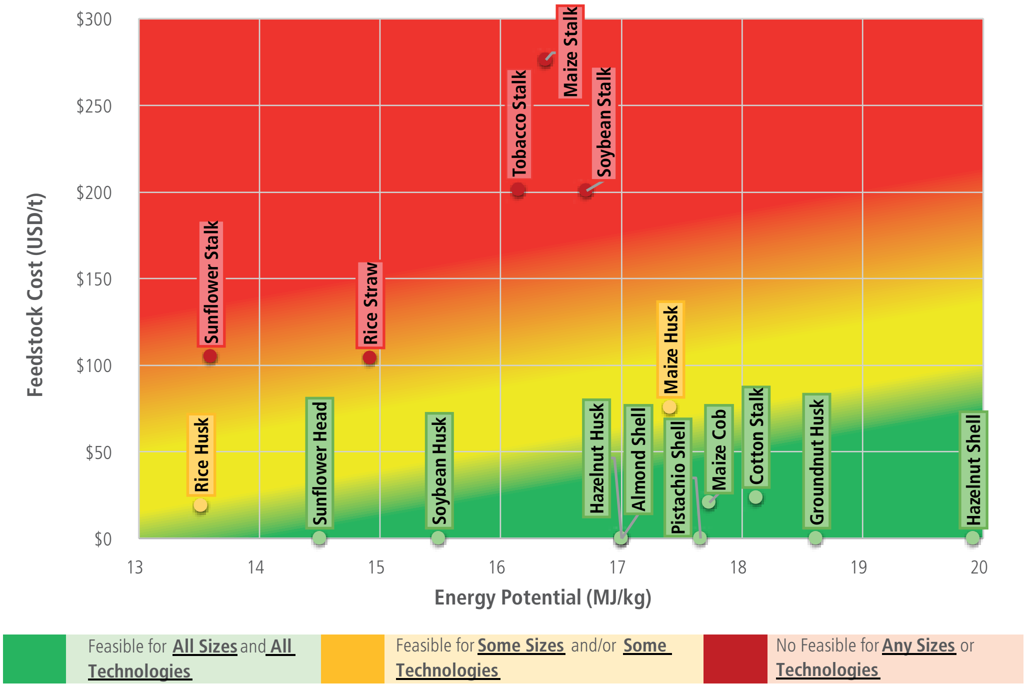
FEEDSTOCK	ENERGY POTENTIAL (MJ/kg)	FEEDSTOCK COST (USD/t)
Maize Stalk	16.4	$276.06
Tobacco Stalk	16.2	$201.35
Soybean Stalk	16.7	$200.51
Sunflower Stalk	13.6	$104.91
Rice Straw	14.9	$104.16
Maize Husk	17.4	$75.72
Cotton Stalk	18.1	$23.61
Maize Cob	17.7	$20.90
Rice Husk	13.5	$19.03
Almond Shell	17.0	$0.00
Groundnut Husk	18.6	$0.00
Hazelnut Husk	19.9	$0.00
Hazelnut Shell	17.0	$0.00
Pistachio Shell	17.7	$0.00
Soybean Husk	15.5	$0.00
Sunflower Head	14.5	$0.00

Note: The exchange rate used was 1 USD = 2.47 TL.

Results of profitability zones maps for briquettes (Figure 34) indicate that, independently of availability, the most promising feedstock for briquette production in Turkey would be the feedstock with energy potentials higher than 15 MJ/kg and with a low feedstock cost. The most promising feedstock for briquette production (green area) would be hazelnut shell, groundnut shell, cotton stalk, maize cob, pistachio shell hazelnut husk, soybean husk, and sunflower head. Rice husk and maize husk (yellow area) might be promising feedstock given the low cost of the former and the high-energy potential of the latter, which might also be profitable for production in large plant sizes.

FIGURE 34.

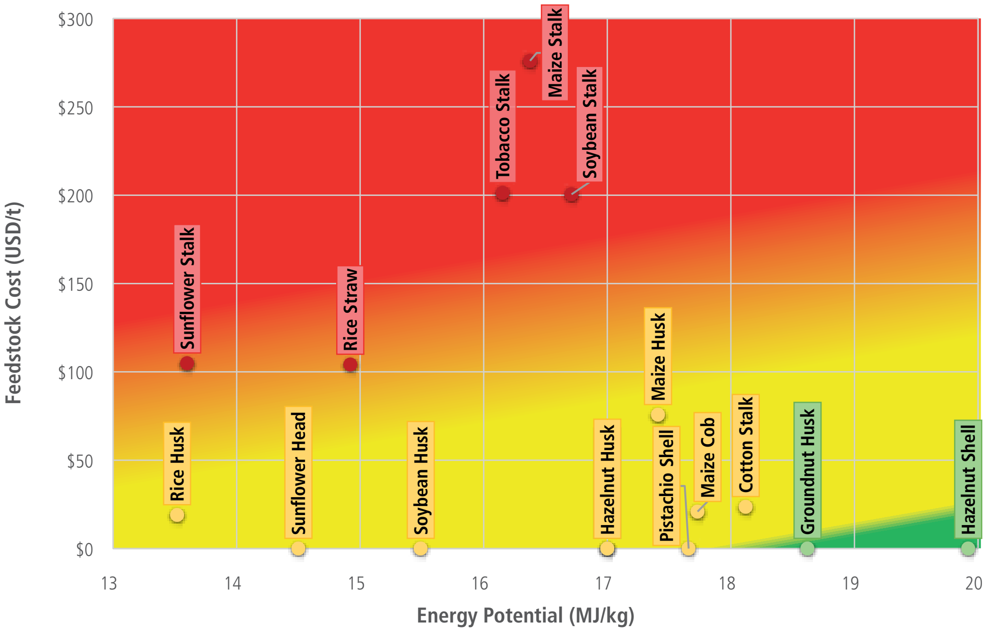
Profitability zone map for the production of briquettes



Conversely, in the case of the pellets industry (Figure 35) only two options are profitable for all plant sizes: groundnut husk and hazelnut shell. This is due to the higher market price of pellets. Other feedstock such as cotton stalk, maize cob, pistachio shell hazelnut husk, soybean husk, sunflower head, rice husk and maize husk might be profitable using large-scale plants only.

FIGURE 35.

Profitability zone map for the production of pellets



Another feature of briquettes and pellets relates to their potential as fuels used to replace fossil fuels currently used in the country in order to reduce their dependence. Biomass-based fuels have the opportunity to increase energy sovereignty and gives added value to biomass residues. According to Özcan *et al.* (Özcan, Gülay *et al.* 2013), the two main fuel options consumed by Turkish households are fuelwood and coal. In order to analyse this potential, the economic performance of briquettes replacing these two fuel options were analysed. For sake of simplicity, only briquettes results will be presented.

NPVs were recalculated using a reference price for fuelwood of 0.14 USD/kg and for coal of 0.28 USD/kg (Yaylacı 2015). Additionally potential revenues needed to account for differences in energy potentials among fuelwood and coal and briquettes produced with different types of feedstock featured by the range in energy potentials. Differences in terms of energy outputs of fuelwood, coal and briquettes were considered by including an additional term that account this equivalence, in the cash flow calculation (see equation 3) and in Table 27.

$$\begin{aligned}
&\textit{Annual Cash Flows}\\
&= \frac{\textit{Fuel Market Price}\left(\frac{USD}{kg\ fuel}\right) * \textit{Annual Production}\left(\frac{kg\ products}{year}\right)}{\textit{Fuel equivalent Factor}\left(\frac{kg\ products}{kg\ fuel}\right)}\\
&\quad - \textit{Annual Production}\left(\frac{kg\ products}{year}\right)\\
&\quad * \textit{Energy Potential}\left(\frac{MJ}{kg\ products}\right) * \textit{Unit Cost}\left(\frac{USD}{GJ}\right) * \frac{1\ GJ}{1000\ MJ}
\end{aligned}$$

Equation 3

TABLE 27.

Equivalency factors for fuel wood and coal

ENERGY POTENTIAL (MJ/kg)	kg PRODUCT/kg FUELWOOD	kg PRODUCT/ kg COAL
10	0.63	3.40
13	0.50	2.72
15	0.42	2.27
18	0.36	1.94
20	0.32	1.70

As a result of this modification in the NPV calculation, Figure 36 and Figure 37 were obtained. These results indicate how there does exist a potential for briquettes and pellets as potential replacements for fuelwood in Turkey. This analysis considers that in total, consumers would be spending the same amount on briquettes or pellets that would provide the equivalent energy of fuelwood or coal.

FIGURE 36.

Comparison of economic potential for briquettes replacing fuelwood

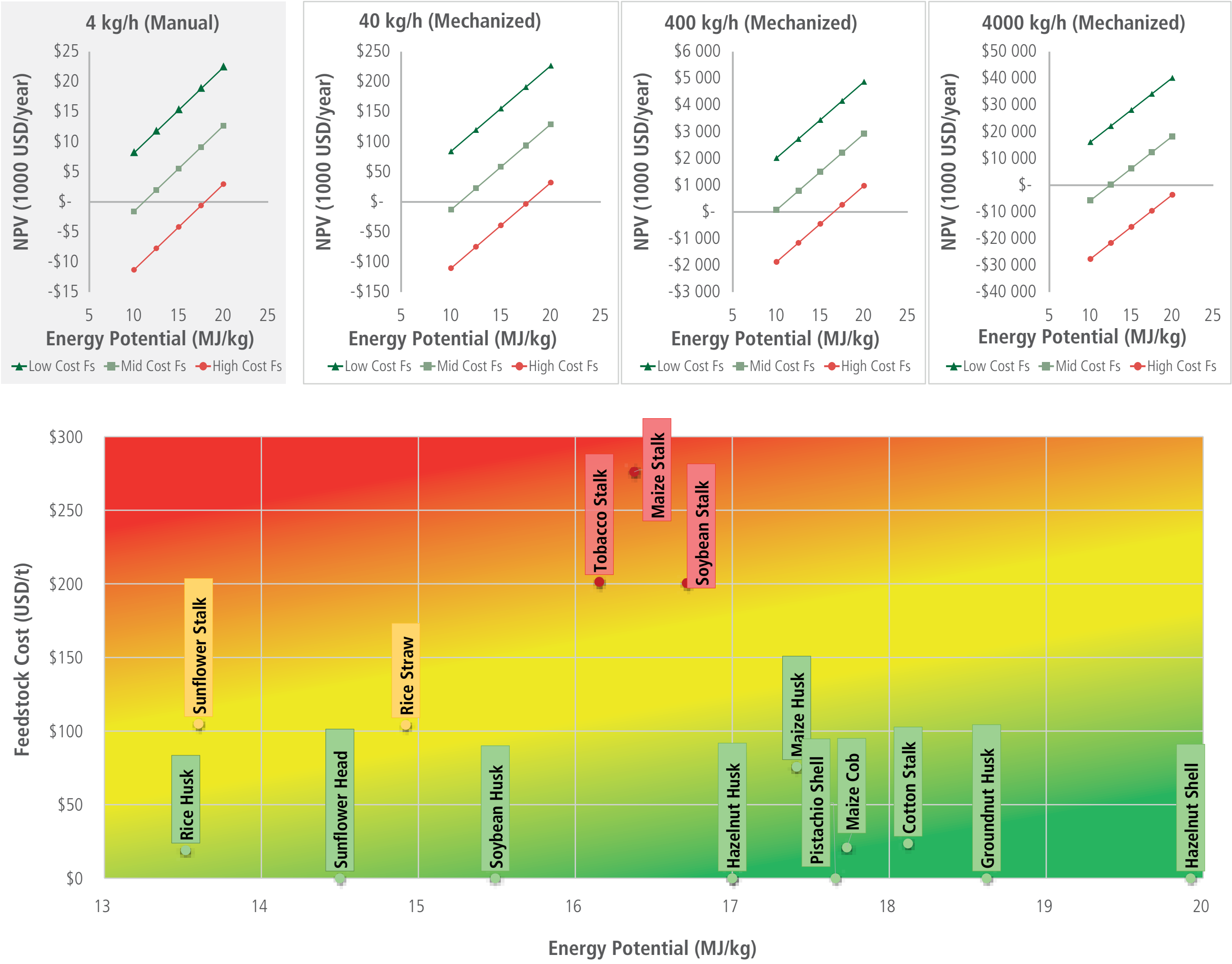
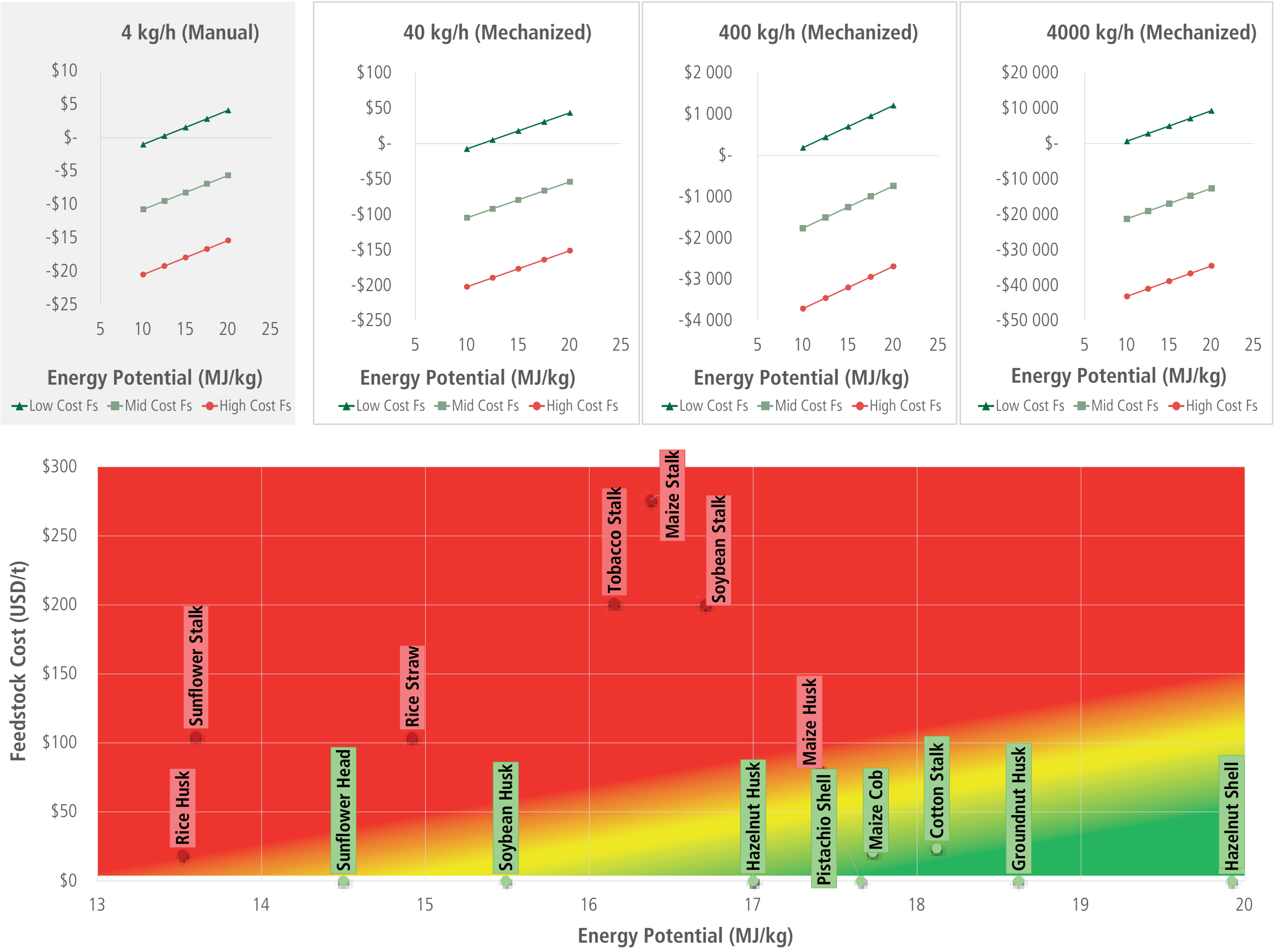


FIGURE 37.

Comparison of economic potential for briquettes replacing coal

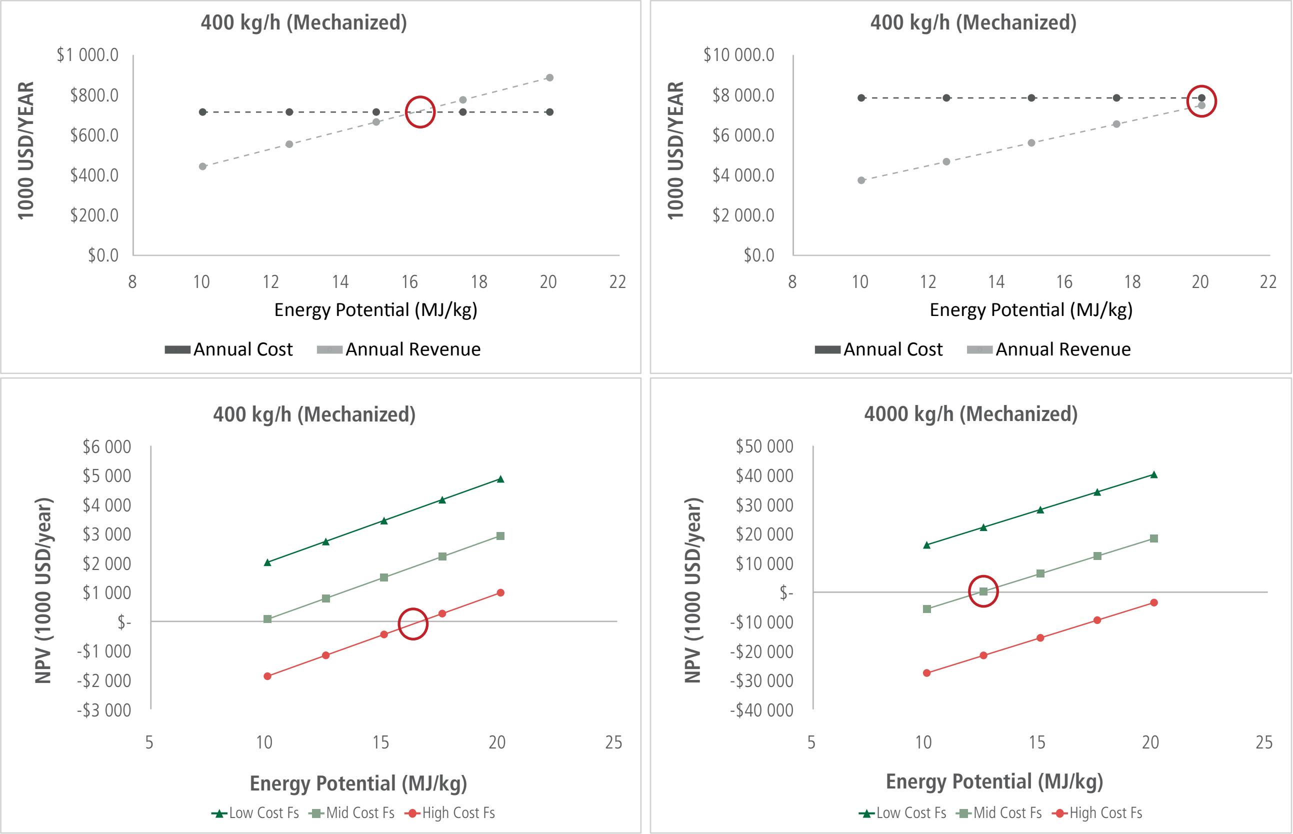


From the above results, it can be noted that briquettes produced from green zone feedstock would be more potentially competitive in those regions where these would be used to replace fuelwood than to replace coal. The explanation of this result is based on the high energy potential of coal (34 MJ/kg) that requires a higher number of briquettes to replace 1 kg of coal compared to the number required to replace 1 kg of fuelwood. This simple feature makes briquettes produced from crop residues potentially more valuable than fuelwood and more competitive with an equivalent market price.

It is also interesting to note that in all cases the highest income is obtained for the largest plant size as expected. However, in the case of briquettes replacing fuelwood the 400 kg/h plant size option allows the use of all low cost and all mid cost feedstock options, and for some high energy potential options (18 MJ/kg) it is also possible to pay a high cost. This behaviour can be better understood using Figure 38, which presents a comparison of annual production costs and revenues obtained for 400 kg/h and 4 000 kg/h at a high feedstock cost of 300 USD/t. In this figure, it can be seen, how even with the high revenue obtained for 4 000 kg/h, the annual cost will be always higher for all energy potential options. As a result, it does not matter the energy quality of feedstock used, these producers would be losing money in time. Conversely, in the 400 kg/h case, briquettes produced using feedstock with energy potentials higher than 17 MJ/kg might be able to generate income, given the fact that these briquettes will be more valuable. This issue is a perfect example of the energy potential importance for bioenergy production, and how the quality of the obtained products might mean a competitive advantage for an industry.

FIGURE 38.

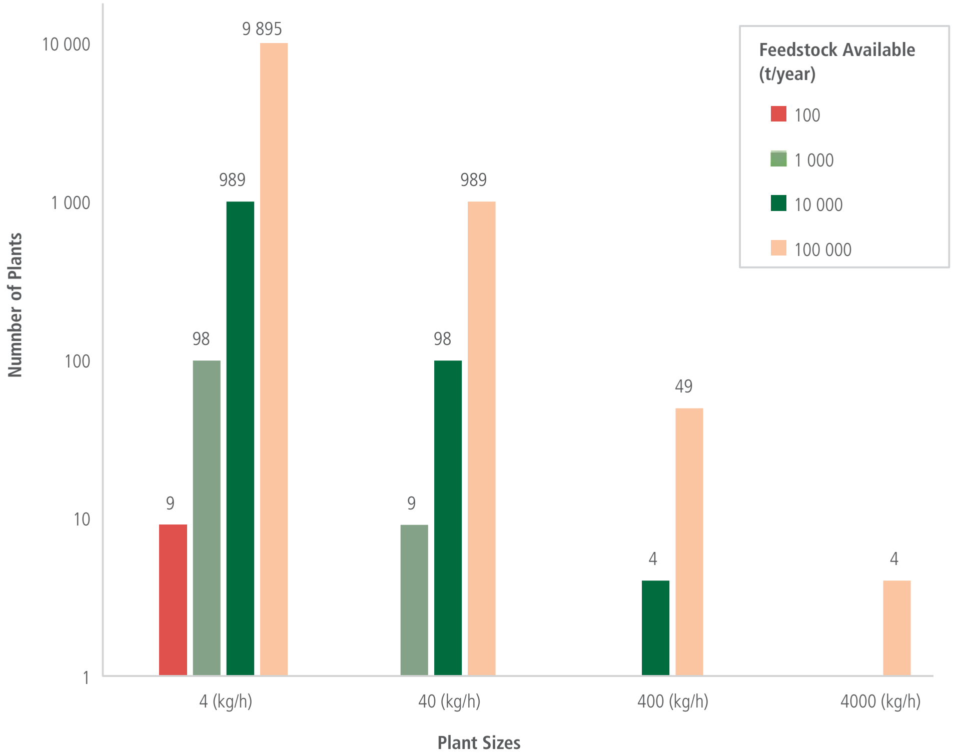
Comparison of annual costs and revenues of briquette production using high cost feedstock options



The next level of analysis considers how, given the feedstock availability, promising feedstock might be used to supply briquette and pellet plants and then what number of households may potentially be supplied. Considering the processing efficiency of briquetting and pelletizing and the same annual output rate, it is possible to estimate the number of plants that can be potentially supplied using the biomass range available (Figure 39).

FIGURE 39.

Number of briquettes or pellets factories potentially supplied with available biomass



Results of the number of plants calculation shows how according to the feedstock demand of each plant size, only the minimum feedstock amount available in a region of a given feedstock intended to be converted in briquettes or pellets is 100 t/year, less feedstock would be needed to supply manual operation (4 kg/h) plants under very specific conditions. However, it is possible that biomass residues producing such small quantities have a number of current uses making it difficult to collect. On the other hand, only biomass residues producing up to 100 000 t/year would be able to supply the largest plant sizes considered (4 000 kg/h). However, larger plant sizes with a larger annual output will be able to supply a larger number of households, compared to small-scale plants.

Considering the heating and cooking demand of typical rural and urban households in Turkey, that based on a literature review was calculated as 9.31 t briquettes or pellets/year/hh for rural areas and 7.03 t briquettes or pellets /year/hh for urban areas, it was possible to estimate the potential number of household that each plant size might be able to supply (Table 28) (TURKSTAT 2011, Özcan, Gülay *et al.* 2013).

TABLE 28.

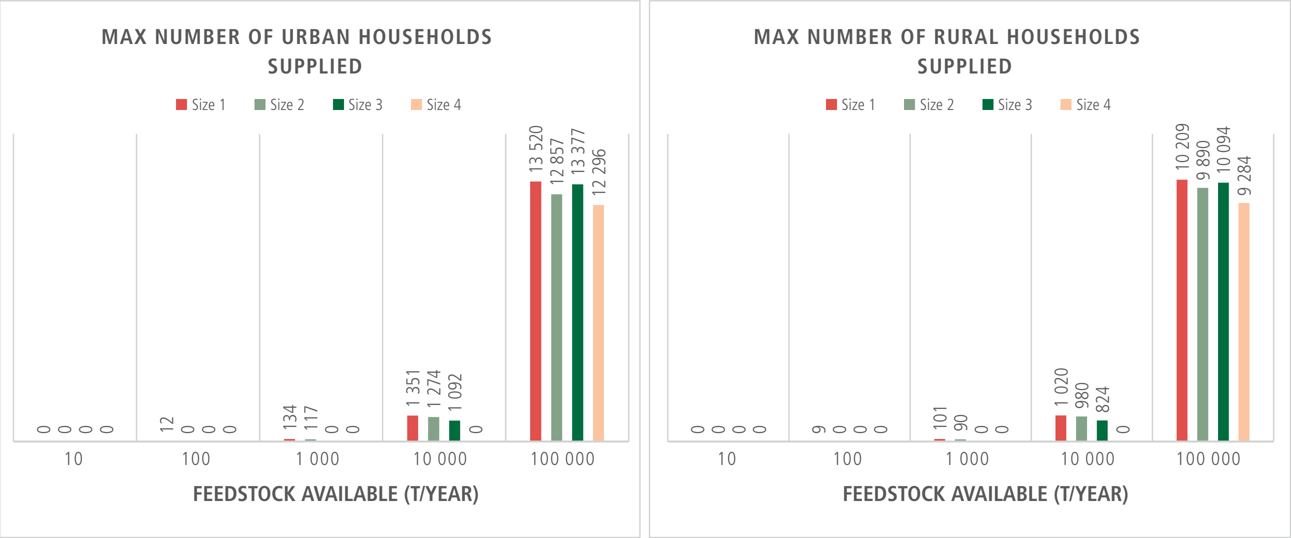
Number of households potentially supplied per plant size

	ANNUAL PRODUCTION			
	SIZE 1	SIZE 2	SIZE 3	SIZE 4
Annual Demand	7.2 t/year	96 t/year	1 920 t/year	21 600 t/year
Rural Households per plant (plant/hh)	0.77	10	206	2 321
Urban Households per plant (plant/hh)	1.02	13	273	3 074

Combining all above figures, it was possible to estimate the maximum number of households that might be supplied per plant size using the range of feedstock available (Figure 40). Thus, it can be noticed how using the maximum feedstock availability the combination of Figure 40 and Table 28 can supply around 13 000 households at urban level and 10 000 households at rural level. Either using a small number of large-scale plants or a large number of small-scale plants, number of households potentially supplied are more or less homogenous. Consequently, the final decision on what plant sizes should be supported in the country would be decided by the capital investment required, type of technology preferred, and the feedstock available and able to be accessed in each particular province. This last particular issue is assessed as follows.

FIGURE 40.

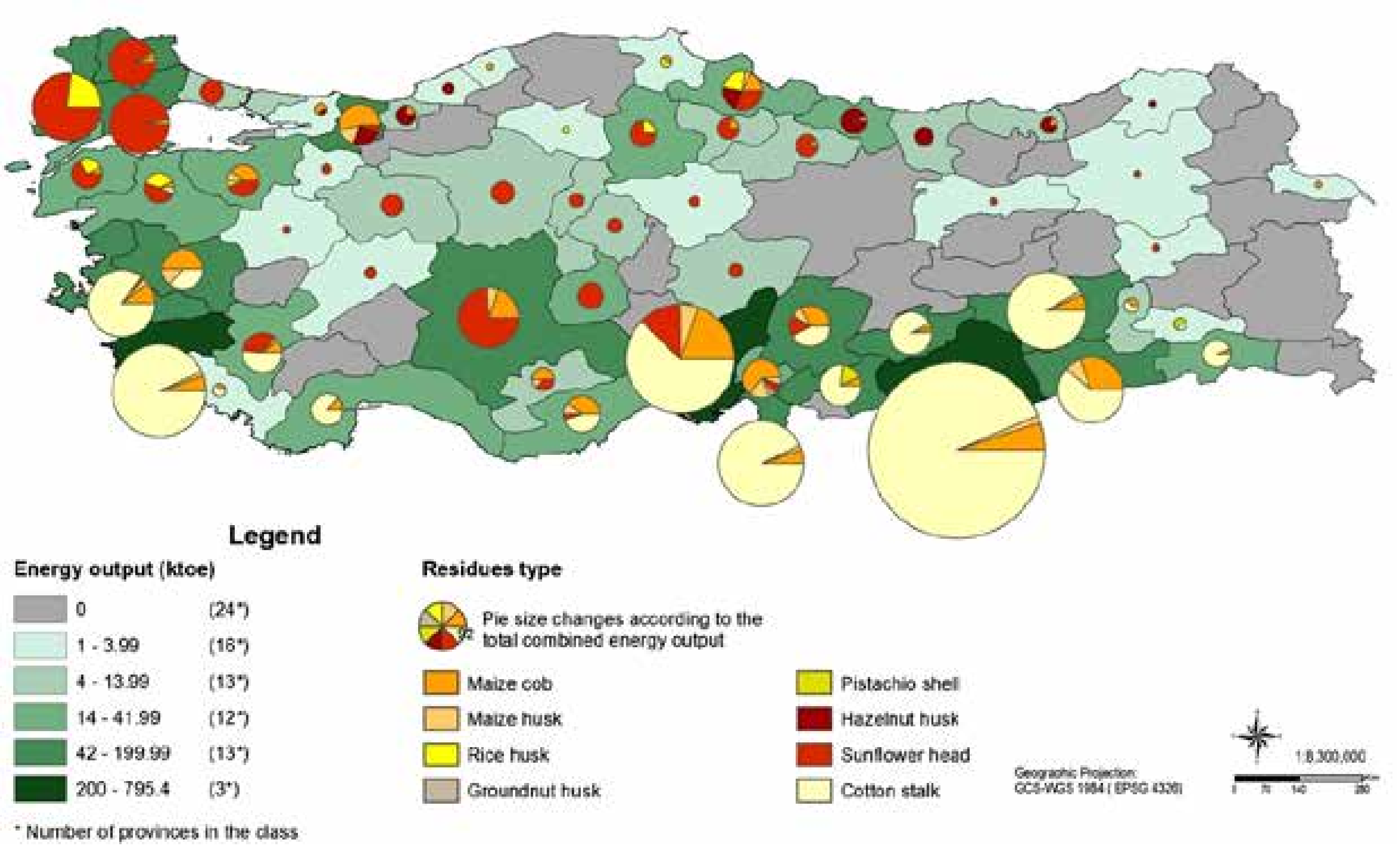
Number of households potentially supplied at urban and rural level



The potential role of briquettes and pellets to meet Turkish renewable energy targets by 2023 was estimated using a combination of technical elements considered in previous steps of this report. Thus, elements such as biomass availability, profitable production capacities, as well as those feedstock options identified as promising, were used to estimate the total potential energy output for biomass converted to briquettes or pellets in Turkey (Figure 41), being able to achieve a total combined energy of 2 939 ktoe. Consequently, it would be possible to cover a big portion of the 3 537 ktoe projected target in Turkey for heating and cooling. Additionally it can be noticed that 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 cob and cotton stalk. This last feedstock shares 60 percent of total potential energy output, being an indicator of the high potential of this biomass residue for bioenergy production.

FIGURE 41.

Total potential energy output (ktoe) from selected biomass residues



It is interesting to notice how based on above results cotton stalk would result in a key feedstock for bioenergy production in Turkey. However, it should also be considered that unlike other feedstock selected for briquette/pellets production cotton stalk is located spread in fields after harvesting, and not centralized at food processing industries. Consequently, factors such as collection, transport and accessibility levels to these residues become crucial. Considering this, the importance of accessibility of biomass residues was analysed through the example of briquettes production based on cotton stalk. This example allows illustrating both the high biomass potential that in theory is not being currently used and how this potential could be used to provide heating and cooking for the Turkish population.

TABLE 29.

Cotton stalk available and quantities available for bioenergy production under different accessibility levels

PROVINCE NAME	REGION NAME	COTTON STALK AVAILABLE	TON ACCESSED PER YEAR			
		t/year	20%	30%	40%	50%
Aydin	Aegean	1 423 919	284 784	427 176	569 568	711 959
Izmir	Aegean	672 184	134 437	201 655	268 873	336 092
Denizli	Aegean	149 033	29 807	44 710	59 613	74 517
Manisa	Aegean	107 089	21 418	32 127	42 836	53 545
Mugla	Aegean	17 989	3 598	5 397	7 196	8 995
Balikesir	Marmara	9 331	1 866	2 799	3 732	4 666
Adana	Mediterranean	1 306 512	261 302	391 954	522 605	653 256
Hatay	Mediterranean	1 196 669	239 334	359 001	478 667	598 334
Antalya	Mediterranean	154 054	30 811	46 216	61 622	77 027
Kahramanmaraş	Mediterranean	126 521	25 304	37 956	50 608	63 260
Mersin	Mediterranean	105 558	21 112	31 667	42 223	52 779
Osmaniye	Mediterranean	11 817	2 363	3 545	4 727	5 908
Sanliurfa	Southeast Anatolia	5 123 235	1 024 647	1 536 971	2 049 294	2 561 618
Diyarbakir	Southeast Anatolia	985 523	197 105	295 657	394 209	492 761
Mardin	Southeast Anatolia	461 497	92 299	138 449	184 599	230 748
Adiyaman	Southeast Anatolia	295 365	59 073	88 610	118 146	147 683
Gaziantep	Southeast Anatolia	232 424	46 485	69 727	92 970	116 212
Sirnak	Southeast Anatolia	126 699	25 340	38 010	50 680	63 350
Batman	Southeast Anatolia	24 002	4 800	7 201	9 601	12 001
Siirt	Southeast Anatolia	8 877	1 775	2 663	3 551	4 438
Kilis	Southeast Anatolia	5 051	1 010	1 515	2 020	2 526

From Table 29, it can be seen how the top producer regions for cotton stalk are in Aegean, Marmara, Mediterranean and Southeast Anatolia regions. Within these regions, the top 5 producers include the Sanliurfa, Aydin, Adana, Hatay and Diyarbakir provinces. Combined production of these five provinces is equivalent to 80 percent of all Turkish production. A minimum accessibility level of 20 percent and a maximum of 50 percent quantities of biomass available per province were also estimated. In some cases biomass available at these accessibility levels was not enough to supply even the smallest plant size (4 kg/h).

TABLE 30.

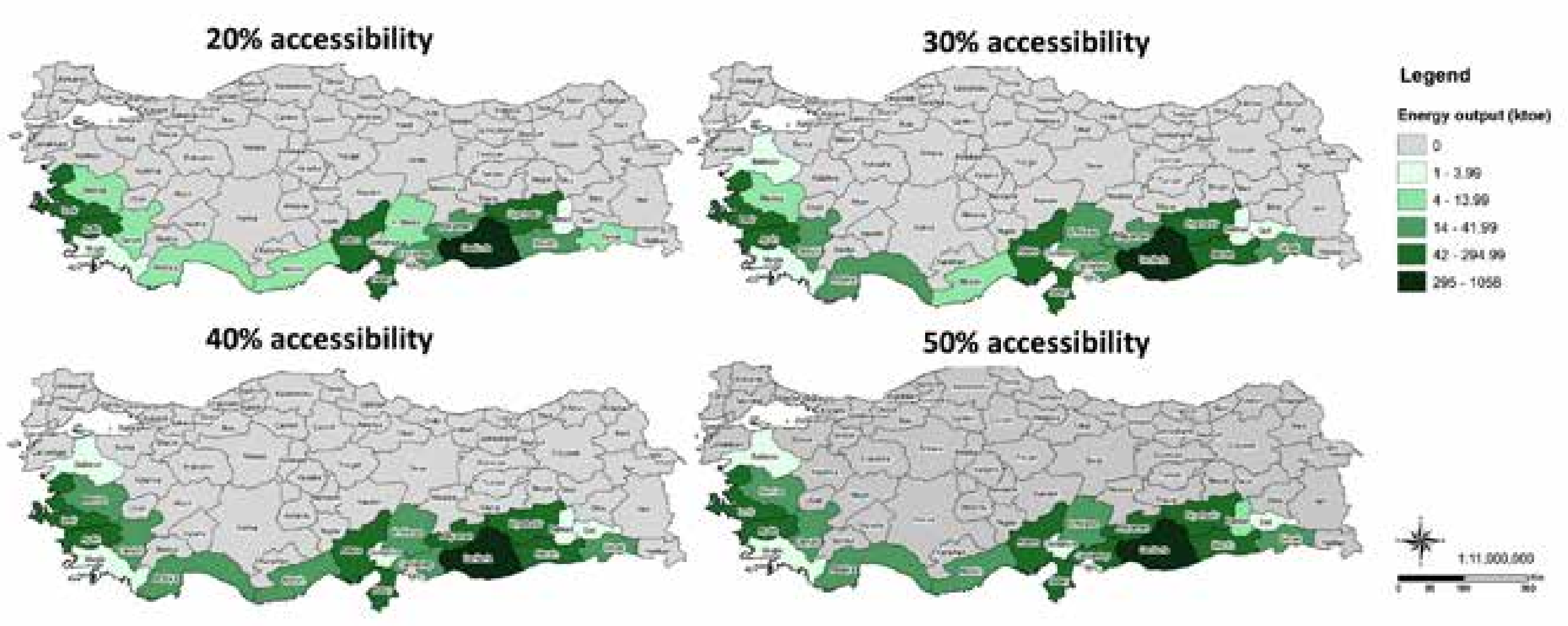
Energy output obtained under different accessibility levels

PROVINCE NAME	REGION NAME	COTTON STALK AVAILABLE	ENERGY OUTPUT (ktoe)			
		t/year	20%	30%	40%	50%
Sanliurfa	Southeast Anatolia	5 123 235	423.14	634.71	846.29	1 057.86
Aydin	Aegean	1 423 919	117.61	176.41	235.21	294.01
Adana	Mediterranean	1 306 512	107.91	161.86	215.82	269.77
Hatay	Mediterranean	1 196 669	98.84	148.25	197.67	247.09
Diyarbakir	Southeast Anatolia	985 523	81.40	122.10	162.79	203.49
Izmir	Aegean	672 184	55.52	83.28	111.04	138.79
Mardin	Southeast Anatolia	461 497	38.12	57.17	76.23	95.29
Adiyaman	Southeast Anatolia	295 365	24.40	36.59	48.79	60.99
Gaziantep	Southeast Anatolia	232 424	19.20	28.79	38.39	47.99
Antalya	Mediterranean	154 054	12.72	19.09	25.45	31.81
Denizli	Aegean	149 033	12.31	18.46	24.62	30.77
Sirnak	Southeast Anatolia	126 699	10.46	15.70	20.93	26.16
Kahramanmaraş	Mediterranean	126 521	10.45	15.67	20.90	26.12
Manisa	Aegean	107 089	8.84	13.27	17.69	22.11
Mersin	Mediterranean	105 558	8.72	13.08	17.44	21.80
Batman	Southeast Anatolia	24 002	1.98	2.97	3.96	4.96
Mugla	Aegean	17 989	1.49	2.23	2.97	3.71
Osmaniye	Mediterranean	11 817	-	1.46	1.95	2.44
Balikesir	Marmara	9 331	-	1.16	1.54	1.93
Siirt	Southeast Anatolia	8 877	-	1.10	1.47	1.83
Kilis	Southeast Anatolia	5 051	-	-	-	1.04

Then considering the energy potential of cotton stalk, the energy output of briquettes was calculated in ktoe for each province and accessibility level (Table 30). These values were calculated for those cases where biomass available was high enough to supply at least one manual scale plant (4 kg/h).

FIGURE 42.

Total national potential energy output (ktoe) from cotton stalk at different accessibility levels

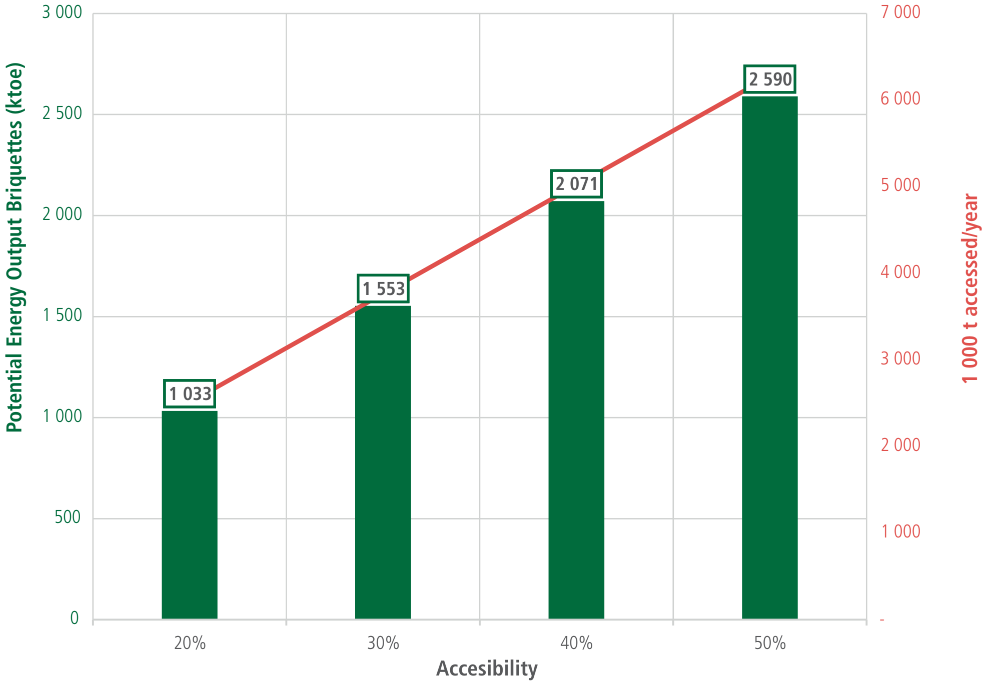


Results on how increasing accessibility levels of cotton stalk, the energy potentials obtained from its briquettes are increased too can be better understood using Figure 42. There it can be noticed how at higher accessibility levels a darker shade of green indicates a larger amount of residues available at a particular province, where more energy would result available for consumers. This effect is clearer in (Figure 43) where potential energy output ranging from 1 033.09 to 2 589.98 ktoe is presented. This result is a clear indicator of the high potential for bioenergy production in Turkey based on biomass residues only, and how increasing the accessibility level might help the country reach national renewable energy targets using profitable options.

The provinces are represented in different shades of green representing the total amount of residues available. The darker the shade of green the larger the amount available in a particular province.

FIGURE 43.

Total national potential energy output (ktoe) at different accessibility levels



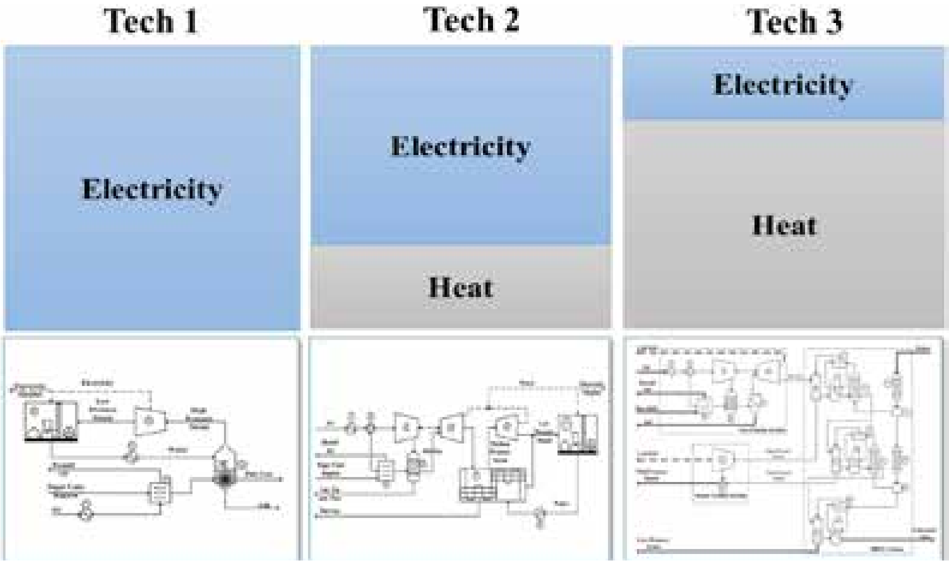
Cogeneration of heat and power results

This section presents the results obtained for cogeneration of heat and power using i) direct biomass residues and ii) biogas produced from wet biomass. The CHP assessment was designed considering different variables that might affect the potential performance and consequently the economic sustainability of CHP production. These variables include energy potential and cost of feedstock as were defined previously. Additionally, technology options were considered to account for differences in operation of CHP plants.

Three technology options were analysed, each referring to a specific configuration of the CHP plant and production targets or needs (Figure 44). Thus, the base line case, referred to as Technology 1 option, considers a standard combination of a biomass boiler and turbine dedicated solely to the production of electricity. The Technology 2 option includes the possibility to recover heat by combining steam turbines and heat recovery systems. This option allows for the production of both heat and electricity, although primarily to produce electricity. The Technology 3 option is based on a combined cycle technology that combines steam and gas turbines and uses a multi-pressure Heat Recovery Steam Generator (HRSG) system.

FIGURE 44.

Technology options considered in BEFS analysis



CHP Scenarios

Due to the nature of cogeneration systems and the fact that they are used to produce both heat and power, three CHP scenarios were built to reflect possible situations that may arise in Turkey and the consequent impacts of changes in the feed in tariff for electricity and the price of heat. Conditions can vary depending on whether the CHP system is locally built and whether the CHP system produces heat and electricity or electricity alone. The three scenarios reflect possible combinations of these conditions.

In the case of the price of electricity, a feed in tariff system is in place in Turkey to support electricity production for renewable energy defined by Turkey´s Renewable Energy Support (YEK) Mechanism on the use of renewable energy sources for electricity generation. This regulation foresees a feed in tariff of 0.133 USD/kWh for power plant facilities based on biomass. Additionally, power plants using mechanical or electro-mechanical equipment produced locally might add a maximum local premium of 0.056 USD/kWh during the first five years of operation (PWC Turkey 2012).

With respect to the price of heat, considering the relatively low number of installed district heating networks across the country (Orhan Mertoglu 2000, Kartal 2013) and the overall tendency of producing heat locally, an average heat price was estimated to be 12 USD/GJ[13]. However, the cost of distributing the heat from the plant to the end user must be taken into account and included in the calculation. Therefore, a conservative assumption would be to assign a 50 percent heat cost to go towards this distribution (Poyry Energy Consulting, 2009). Thus, the heat price used for calculations was 6 USD/GJ. Based on this, three scenarios were established.

Scenario 1 is the baseline scenario that receives a lower overall feed-in tariff. The CHP system is not locally built and produces both heat and electricity. In this case, the feed-in tariff is 0.133 USD/kWh, the heat price is 6 USD/GJ, and this is the worst-case scenario.

Scenario 2 assumes that CHP plants are built locally. In this case the CHP plant will receive the feed in tariff plus the local content addition. The total feed-in tariff is 0.189 USD/kWh and the heat price is 6 USD/GJ.

reflects the uncertainty in the price of heat, distribution system and in the heat market for cogeneration plants. In this scenario CHP plants are assumed to be locally built and therefore receive the 0.189 USD/kWh feed-in tariff, however heat is not sold but converted into electricity[14]. Due to this, electricity is the only product of the CHP plant and this is the best-case scenario.

Direct Combustion of Biomass Residues

The first step in the analysis is to assess the economic viability of CHP systems. The indicator used to illustrate this is the Net Present Value, i.e. the overall profitability of the system over a 20-year period considering the investment requirements and the returns from the system. The economic profitability is closely tied to technology options, system size, cost of feedstock and the feedstock energy content. The first set of results is presented for scenario 1, the baseline scenario.

The results obtained for scenario 1 are reported in Figure 45. The results show how technology options have an important role on the profitability of CHP plants. Technology option 3 is the most efficient and most profitable. In practical terms these results confirm the notion that investing in more efficient technology results in better use of energy contained in biomass and yields higher production rates of heat and electricity. As a result, plants using technology option 3 will achieve higher revenues, compared to lower efficiency technologies such as Technology option 1, or other less advanced CHP technologies such as Technology option 2. Thus, it can be inferred that cogeneration of heat and power (Technology option 3 and Technology option 2) is more cost effective than to generate electricity alone (Technology option 1). Three levels of feedstock cost are considered: no cost (blue), medium cost (green), high cost (red). A comparison of the above results considering the three energy potential levels used in this analysis reveals how the energy contained in biomass is a key variable affecting the obtained energy output. This feature can be directly noticed in the different electricity production capacities (upper x-axis) across technologies and energy potentials.

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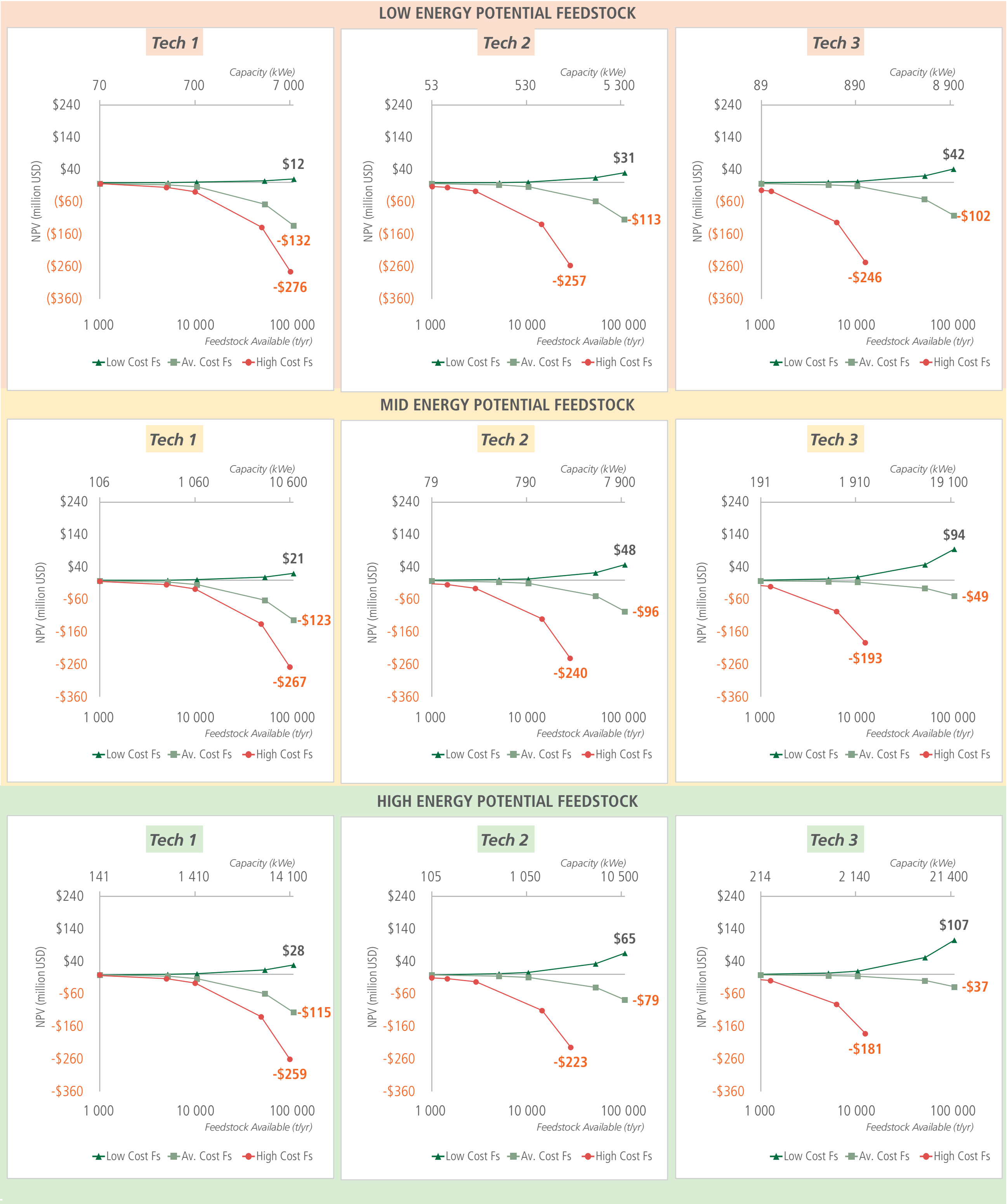
[13] Heating costs total of a building with 24 houses in Ankara. Total 1 month consumption is 34 490 kWh, costs 3 915 TL (1 kWh = 3.6 MJ). Therefore, the current heat cost is 12 USD/GJ.

[14] This requires additional investment in equipment. The additional investment amount is captured in the economic analysis.

FIGURE 45.

Combined profitability results for scenario 1



The result outlined above reinforces the idea of the importance of technology and energy potential of feedstock on the profitability of a bioenergy business. In addition to technology and energy potential of the feedstock, feedstock costs can also affect the economic performance of the plant. Figure 45 details the range of feedstock cost according to the energy potential. It can be noticed how over the range of feedstock availability (1 000 – 100 000 t/year) and the different plant capacities that can be established, only those feedstock with a low cost (<35 USD/t) have a positive profitability over time. This result is a clear indicator of the role of feedstock cost on biomass-based projects, but also indicates how there must exist a price ceiling that can be paid for a feedstock, according to the technology used and the energy quality of feedstock.

TABLE 31.

Maximum feedstock price scenario 1

ENERGY POTENTIAL (MJ/KG)	MAX-FEEDSTOCK COST (USD/t)		
	TECH1	TECH 2	TECH 3
<13	USD 19	USD 43	USD 45
<15	USD 23	USD 51	USD 99
<17	USD 24	USD 55	USD 106
<19	USD 30	USD 66	USD 112

Note: The exchange rate used was 1 USD = 2.47 TL

Table 31 summarizes the maximum feedstock prices that CHP producers would be able to pay for the biomass according to their energy potential and the technology used to transform it into heat and electricity. These results indicate how according to the energy potential, a feedstock would be more valuable than others and consequently it would be possible to pay a higher price for it. This result is also important for CHP producers in the sense that it is a clear indicator about the resilience that this project might have to a change in feedstock prices, due to shortages in production, increases in feedstock prices, or just because biomass producers raise their prices in order to obtain more revenue. Thus from Table 31 it can be inferred that plants producing heat and power at high efficiency levels will be able to adapt better to changes in feedstock costs, especially for high value feedstock such as those with energy potential higher than 17 MJ/kg.

In order to contextualize results for those feedstock identified as available in the natural resources module and that can be technically used in CHP applications, profitability zones maps were populated with the collection costs and energy potentials summarized in Table 32.

TABLE 32.

Summary of energy potentials and collection cost for feedstock identified as available for bioenergy production

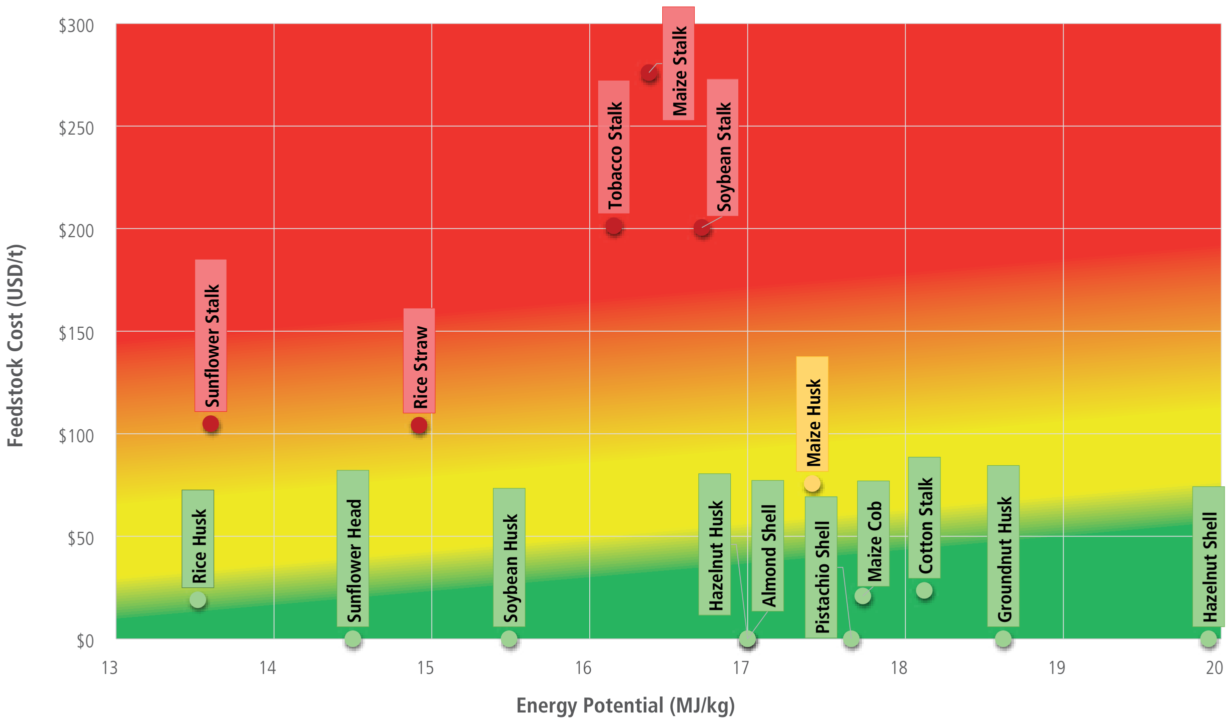
FEEDSTOCK	ENERGY POTENTIAL (MJ/KG)	FEEDSTOCK COST (USD/T)
Maize Stalk	16.4	$276.06
Tobacco Stalk	16.2	$201.35
Soybean Stalk	16.7	$200.51
Sunflower Stalk	13.6	$104.91
Rice Straw	14.9	$104.16
Maize Husk	17.4	$75.72
Cotton Stalk	18.1	$23.61
Maize Cob	17.7	$20.90
Rice Husk	13.5	$19.03
Almond Shell	17.0	$0.00
Groundnut Husk	18.6	$0.00
Hazelnut Husk	17.0	$0.00
Hazelnut Shell	19.9	$0.00
Pistachio Shell	17.7	$0.00
Soybean Husk	15.5	$0.00
Sunflower Head	14.5	$0.00

Note: The exchange rate used was 1 USD = 2.47 TL.

It is important to highlight that Table 32 values represent a snapshot in time where costs were calculated under a specific set of specific conditions and assumptions. These feedstock might change during validation in the field considering changes in accessibility, machinery used, labour or even the establishment of a market price due to competitive uses. Consequently, the following results are intended to explain how conditions found in Table 32 can be used to screen feedstock alternatives.

FIGURE 46.

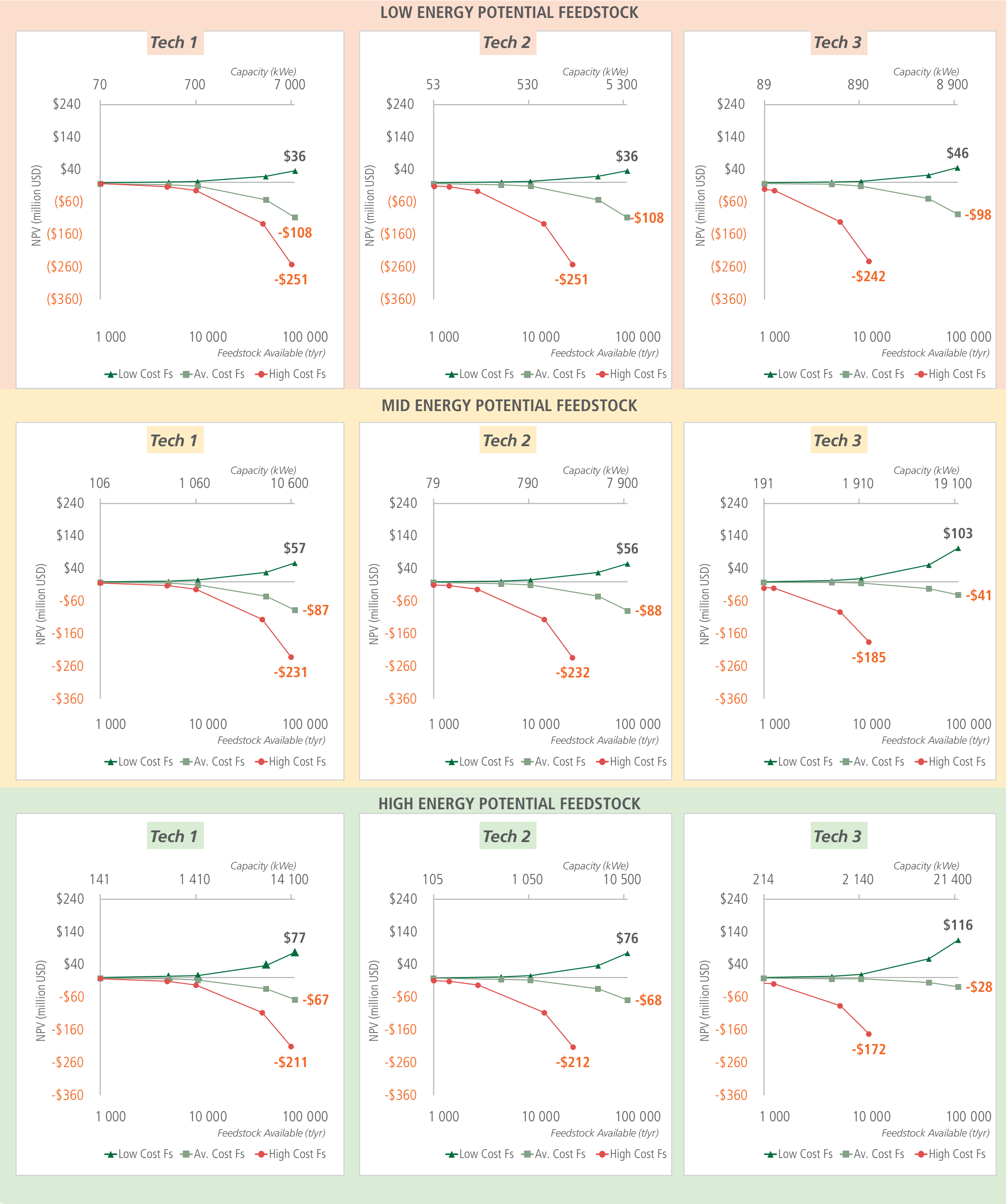
Profitability zones for scenario 1



Using profitability zones maps (Figure 46) it can be stated that under the standard feed-in tariff (0.133 USD/kWh) and established heat cost conditions (6 USD/GJ), the top 10 most promising options from a profitability point of view are: hazelnut shell, groundnut husk, cotton stalk, maize cob, pistachio shell, almond shell, hazelnut husk, soybean husk, sunflower head and rice husk.

FIGURE 47.

Combined profitability results for scenario 2



In scenario 2, the assumption of using equipment produced locally in Turkey increases the feed-in tariff to 0.189 USD/kWh. The average effect of this increase in revenue over all plant sizes and technologies was to increase the average profitability by 23 percent. This change in profitability increased the price ceiling paid for feedstock by 37 percent (Table 33).

TABLE 33.

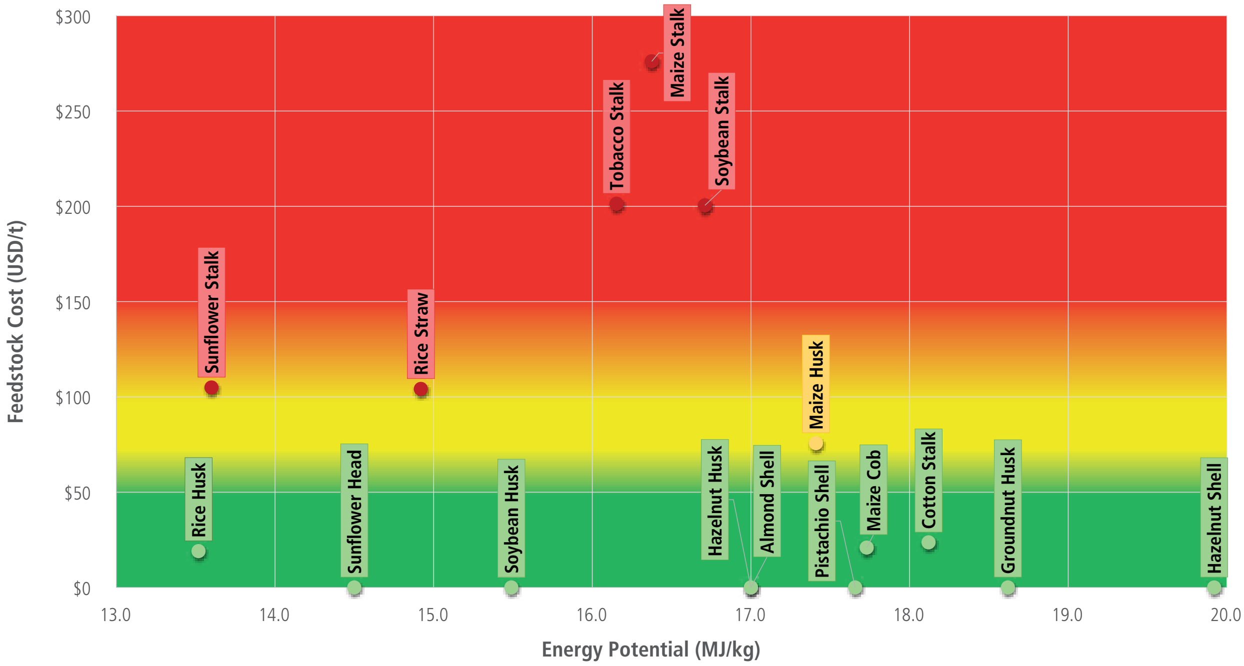
Maximum feedstock price scenario 2

ENERGY POTENTIAL (MJ/KG)	MAX-FEEDSTOCK COST (USD/t)		
	TECH1	TECH 2	TECH 3
<13	USD 53	USD 51	USD 49
<15	USD 62	USD 60	USD 109
<17	USD 71	USD 68	USD 123
<19	USD 80	USD 77	USD 123

Note: The exchange rate used was 1 USD = 2.47 TL.

FIGURE 48.

Profitability zones for scenario 2



The combination of results from Table 33 and Figure 48 show that although the local premium has a positive effect on average profitability, the effects on maximum feedstock price were not high enough to include additional feedstock. As a result the top 10 promising feedstock remain the same..

FIGURE 49.

Combined profitability results for scenario 3

TABLE 34.

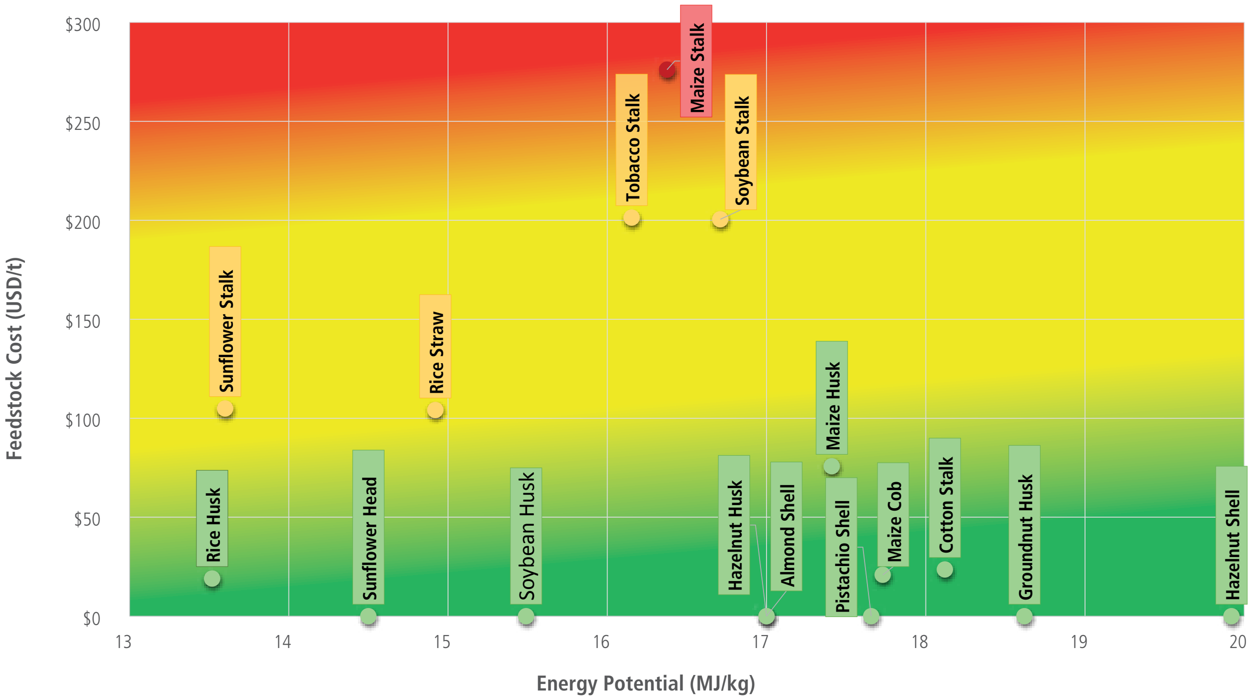
Maximum feedstock price scenario 3

ENERGY POTENTIAL (MJ/KG)	MAX-FEEDSTOCK COST (USD/t)		
	TECH1	TECH 2	TECH 3
<13	USD 53	USD 51	USD 49
<15	USD 62	USD 60	USD 109
<17	USD 71	USD 68	USD 123
<19	USD 80	USD 77	USD 123

Note: The exchange rate used was 1 USD = 2.47 TL.

FIGURE 50.

Profitability zones for scenario 3



More specifically, modifications considered in scenario 3 increases average profitability by 73 percent and led to an increase in the maximum feedstock price by 53 percent (Table 34). This change increased the number of feedstock that can be considered as promising and potentially profitable (green and yellow areas in Figure 50).

Profitability zones identified for scenario 1, 2 and 3 shows how a competitive production for most of feedstocks might be possible even under current conditions (feed-in tariff and heat price), and how premiums and changes in production schemes (converting heat surplus into electricity) would largely increase the overall profitability. In this sense, it is important to understand the differences in capital investment among different production scenarios and plant capacities based on the energy potential of feedstock.

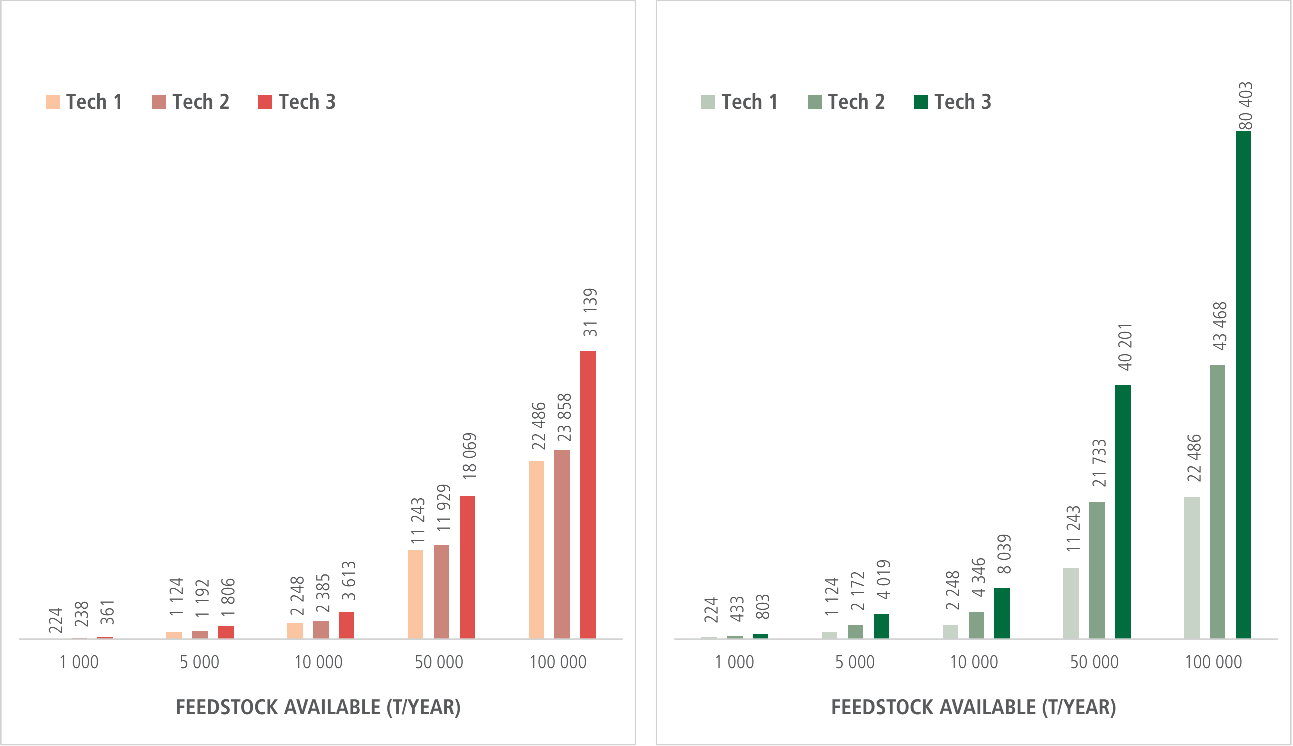
FIGURE 51.

Comparison capital investment requirements for scenarios 1, 2 and 3 under different plant sizes

Total electricity output of CHP systems depends on two main factors: energy potential of feedstock and amount of heat converted into electricity. Combination of these two factors will increase or reduce the annual electricity output and as a result the electricity capacity. These features are presented in Figure 51. Additionally, Figure 51 demonstrates that the maximum electricity production capacity under a standard operation (scenario 1 and 2), is achieved using the maximum feedstock quantity (100 000 t/year), the highest energy potential (20 MJ/kg) and Tech 3 (advanced technology). Thus, It is possible to establish a 3 000 kWe plant (remaining energy is dedicated to produce heat). This plant would cost around USD 9 million, equivalent to 3 200 USD/kW. This value is in agreement with 3 000-6 000 USD/kW reported in literature for similar operation plants (C2ES , IRENA 2012). Conversely for the modified operation (scenario 3) using same amount of feedstock, energy potential and technology, but converting heat surplus into electricity, it is possible reach a capacity 18 000 MW investing USD 24 million. Therefore, electricity production at this level can be relatively expensive and although potential profit might be high, investment required is also high.

FIGURE 52.

Comparison of number of households potentially supplied scenarios 1, 2 and 3



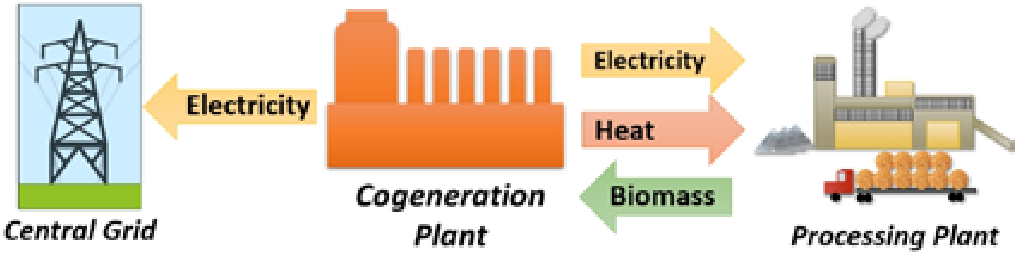
An additional incentive to favour electricity over heat (scenario 3) is the number of households that might be potentially supplied. Considering an average household heat demand of 58 GJ/year/hh and 4 200 kWh/year/hh (Yaylacı 2015), as well as the potential energy production capacities of different production scenarios, it was possible to calculate the number of households that might be potentially supplied using heat and electricity produced using CHP systems (Figure 52). This figure shows how producing only electricity, due to the technological modification in scenario 3, can actually duplicate the number of households supplied per CHP plant when compared to the two other scenarios where CHP plants are producing both heat and electricity.

Based on the results obtained above, a number of recommendations can be made to allow for a profitable production in CHP plants:

- Use high efficiency technologies producing heat and electricity;
- Place a higher preference on feedstock with high-energy potentials;
- Place a higher preference on feedstock located at processing plants;
- Promote the use of equipment locally produced (scenario 2); and
- Heat surplus should be converted to electricity, so that only electricity is produced (scenario 3).

FIGURE 53.

Most profitable production scheme for CHP from direct biomass in Turkey



Thus, the most profitable scheme for CHP production, under the assessment conditions, would be CHP facilities attached to processing plants where the biomass used as fuel is locally produced and available for direct use in cogeneration plants at a low cost. In turn, CHP plants supply heat and electricity to the processing plant. Large electricity surpluses are usually obtained and can be directly sold to the central grid at the feed-in tariff (Figure 53). Additionally, in the case where electromechanical and electrical equipment produced locally in Turkey is favoured, the CHP plant would receive an additional premium, increasing business profitability even more. In special cases, feedstock located in the field can also be considered as long as collection or market prices do not exceed the price ceilings identified in Tables 31, 33 and 34. In this sense, these plants would be a preferred option for stand-alone CHP plants where all produced heat should be transformed into electricity and sold to the central grid.

Considering the above discussion, the list of feedstock suggested/recommended for Turkey is summarized in Table 35, after considering collection costs calculated under the current country situation and energy potentials. It should be noted that additional feedstock might be included or excluded from this list depending on improvements in collection methods that may reduce collection costs or changes in alternative uses that create competitive markets for Table 35 feedstock.

TABLE 35.

List of promising feedstock for CHP production in Turkey

CROP-RESIDUE TYPE		LOCATION	COLLECTION STATUS	CHP OPTION	TOTAL COST (USD/t)	ENERGY POTENTIAL (MJ/kg)
Hazelnut	Shell	processing	Collected	Attached Production - Direct Combustion	$0	19.9
Pistachio	Shell	processing	Collected	Attached Production - Direct Combustion	$0	17.7
Maize	Husk	processing	Collected	Attached Production - Direct Combustion	$76	17.4
Soybean	Husk	processing	Collected	Attached Production - Direct Combustion	$0	15.5
Almond	Shell	processing	Collected	Attached Production - Direct Combustion	$0	17.0
Rice	Husk	processing	Collected	Attached Production - Direct Combustion	$19	13.5
Groundnut	Husk	processing	Collected	Attached Production - Direct Combustion	$0	18.6
Maize	Cob	field	Collected	Stand Alone - Direct Combustion	$21	17.7
Hazelnut	Husk	field	Collected	Stand Alone - Direct Combustion	$0	17.0

Note: The exchange rate used was 1 USD = 2.47 TL.

In the last stage of the assessment, the profitable production conditions were applied to the list of feedstock selected as promising for CHP production in Turkey. Moreover, feedstock availability by province estimated in the Natural Resource Assessment was also considered. Thus, it was possible to create Table 36, which shows the plant capacities that might be supplied using feedstock in Table 35. Feedstock selected included: almond shell, maize cob, maize husk, groundnut husk, pistachio shell, rice husk, hazelnut husk, hazelnut shell, and soybean husk. Then the feedstock potentially available and the plant capacities that might be supplied with these amounts were calculated, excluding those that were not profitable. As a result, it was found that almond shell and pistachio shell, despite being promising options, the quantities available were not high enough to supply minimum profitable sizes due to their energy potentials and cost. Along these lines, the most promising feedstock in terms of quantities, energy potential, and cost were maize cob and maize husk, given the large availability of them. This is particularly true in Adana, Sanliurfa and Mardin provinces, where it would be possible to establish the largest profitable plants.

TABLE 36.

Potential electricity generation capacities of CHP direct combustion system in provinces producing most promising residues

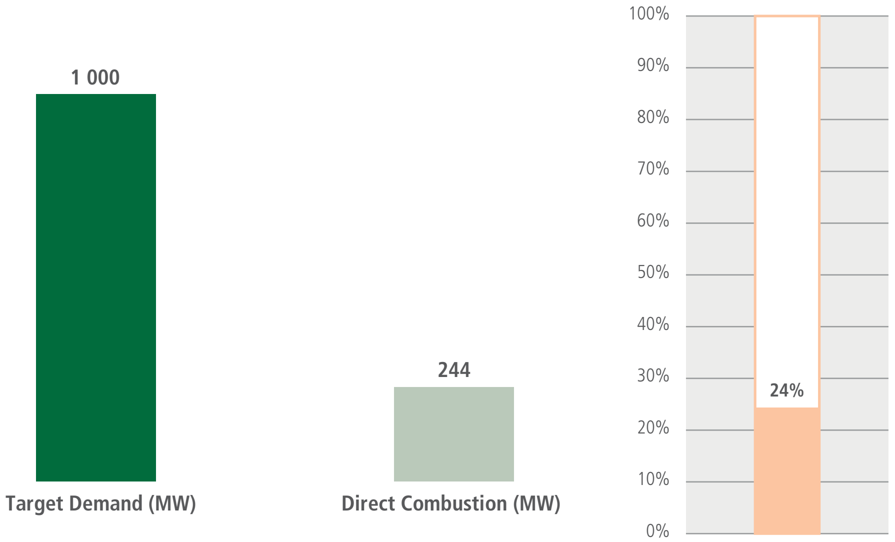
PROVINCE NAME	ELECTRICITY CAPACITY (MW)									TOTAL CAPACITY PROVINCE (MW)
	ALMOND SHELL	MAIZE COB	MAIZE HUSK	GROUNDNUT HUSK	PISTACHIO SHELL	RICE HUSK	HAZELNUT HUSK	SOYBEAN HUSK	HAZELNUT SHELL	
Adana	-	25.8	7.0	0.8	-	-	-	-	-	33.6
Sanliurfa	-	17.2	4.7	-	2.0	-	-	-	-	23.9
Mardin	-	14.2	3.9	-	-	-	-	1.0	-	19.0
Sakarya	-	10.3	2.8	-	-	-	3.7	-	1.3	18.0
Osmaniye	-	10.6	2.9	0.6	-	-	-	-	-	14.1
Manisa	-	9.1	2.5	-	-	-	-	-	-	11.5
Samsun	-	3.0	0.8	-	-	3.0	2.9	-	1.0	10.8
Konya	-	8.2	2.2	-	-	-	-	-	-	10.4
Edirne	-	-	-	-	-	9.0	-	-	-	9.0
Kahramanmaraş	-	6.1	1.7	-	-	-	-	-	-	7.8
Mersin	-	5.8	1.6	-	-	-	-	-	-	7.3
Ordu	-	-	-	-	-	-	5.3	-	1.8	7.1
Izmir	-	5.2	1.4	-	-	-	-	-	-	6.6
Aydin	-	5.2	1.4	-	-	-	-	-	-	6.6
Diyarbakir	-	4.5	1.2	-	-	-	-	-	-	5.8
Hatay	-	4.5	1.2	-	-	-	-	-	-	5.7
Bursa	-	4.2	1.1	-	-	-	-	-	-	5.3
Duzce	-	1.0	-	-	-	-	2.5	-	0.9	4.4
Giresun	-	-	-	-	-	-	2.9	-	1.0	3.8
Karaman	-	2.8	0.8	-	-	-	-	-	-	3.6
Gaziantep	-	1.3	-	-	2.3	-	-	-	-	3.6
Balikesir	-	0.7	-	-	-	2.7	-	-	-	3.4
Trabzon	-	0.6	-	-	-	-	1.7	-	0.6	2.9
Çanakkale	-	0.7	-	-	-	2.0	-	-	-	2.7
Denizli	-	2.0	0.5	-	-	-	-	-	-	2.6
Kirklareli	-	1.1	-	-	-	0.5	-	-	-	1.6
Antalya	-	1.6	-	-	-	-	-	-	-	1.6
Ãorum	-	-	-	-	-	1.5	-	-	-	1.5
Kocaeli	-	1.1	-	-	-	-	-	-	-	1.1
Zinguldak	-	-	-	-	-	-	1.0	-	-	1.0
Amasya	-	1.0	-	-	-	-	-	-	-	1.0
Adiyaman	-	0.9	-	-	-	-	-	-	-	0.9
Siirt	-	-	-	-	0.8	-	-	-	-	0.8
Batman	-	0.8	-	-	-	-	-	-	-	0.8
Sinop	-	-	-	-	-	0.7	-	-	-	0.7
Tekirdag	-	-	-	-	-	0.7	-	-	-	0.7
Tokat	-	0.6	-	-	-	-	-	-	-	0.6
Mugla	-	0.6	-	-	-	-	-	-	-	0.6

PROVINCE NAME	ELECTRICITY CAPACITY (MW)									TOTAL CAPACITY PROVINCE (MW)
	ALMOND SHELL	MAIZE COB	MAIZE HUSK	GROUNDNUT HUSK	PISTACHIO SHELL	RICE HUSK	HAZELNUT HUSK	SOYBEAN HUSK	HAZELNUT SHELL	
Igdir	-	0.5	-	-	-	-	-	-	-	0.5
Bartin	-	0.5	-	-	-	-	-	-	-	0.5
Total Capacity Feedstock (MW)	-	151.8	37.6	1.4	5.1	20.2	20.0	1.0	6.6	

Additionally, and taking into consideration all potential profitable plants, it is possible to reach a combined production capacity based on direct combustion of biomass residues of 244 MW. This amount would enable meeting 24 percent of the 1 000 MW energy Turkish target (Figure 54).

FIGURE 54.

Comparison of combined production capacity of CHP from direct residues and Turkish renewable energy target for electricity from biomass

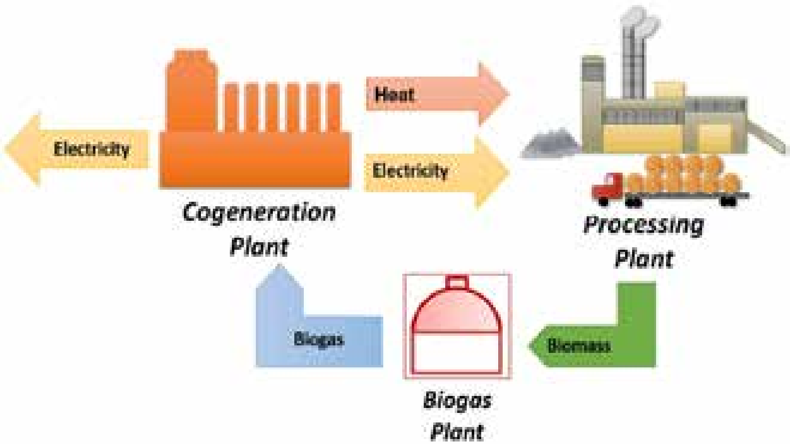


Biogas to electricity results

The above results were obtained for feedstock that can be burnt directly to produce energy in CHP plants. However, some feedstock cannot be directly burned because either their water content is too high or ashes produced during combustion are high too. In these specific cases the most technically appropriate solution is to upgrade these feedstock into a superior energy form. In this sense, biogas production results as a convenient option to extract the energy potential contained in wet biomass. Technical production conditions identified previously apply also for CHP production from biogas with a slight modification as is shown in Figure 55. This scheme takes advantage of the large feedstock available rates that otherwise could not be converted into bioenergy due to the high water contained and transform it into useful energy as heat and electricity.

FIGURE 55.

Most profitable production scheme for CHP from direct biomass in Turkey



Profitability was assessed again under the three scenarios described in the previous section, for four nominal capacities[15] of electricity production (250, 1 000, 10 000 and 50 000 kWe) from biogas. In this case, and contrary to CHP direct combustion, plant sizes were predefined for biogas production. This is due to fact that the biogas burned will have relatively homogenous composition, therefore the electricity potential will be about the same for all feedstock considered. Therefore, in this particular case, feedstock quality variable will be considered using a new approach explained below.

Scenario 1 results presents the NPV (calculated at the feed-in tariff) of different CHP plants based on biogas obtained from biomass residues, under 4 different electricity production capacities, three different feedstock costs and introducing on the X-axis a new variable: Realistic Methane Potential (RMP). The RMP was used as an indicator for identifying the potential to produce biogas considering production conditions such as hydraulic retention time, total solids, volatile solids and temperature regime. The combination of all these elements is considered in Hashimoto's equation (equation 4) and is a good indicator of the realistic production rates of methane of a specific feedstock under a given set of conditions.

$$y = \frac{B_0 \cdot S_0}{HRT}\left(1 - \frac{K}{HRT \cdot \mu_m - 1 + K}\right) \quad (20^{\circ}\mathrm{C} < \mathrm{T} < 60^{\circ}\mathrm{C})$$

Equation 4

---

[15] These nominal capacities are indicative values used to represent differences in plant sizes. In practice electricity capacities of CHP are related to the relative quantities of electricity and heat produced, and might be smaller or larger depending on the quantities of heat produced and used as it was shown in the CHP direct combustion section.

FIGURE 56.

Combined profitability results for scenario 1

Results of scenario 1 indicate that the feed-in tariff and heat price are not high enough to guarantee a profitable production for mid and high cost feedstock (Figure 56). As a result, only a specific set of feedstock fulfilling certain conditions of cost, RMP and plant size would be profitable. This result is better understood in Table 37. There it can be noted how the minimum RMP that biogas feedstock should have is 48, and for this RMP only plant sizes larger than 1 000 kWe would result profitable enough to pay for a small amount for feedstock. On the other hand, only very valuable feedstock (RMP 74) would be able to include a 1 000 kWe plant size as a profitable option. The above results indicate how under current conditions (feed-in tariff and heat price), operating only high quality feedstock produced at processing plants directly converted into biogas and used in attached cogeneration facilities, would be profitable.

TABLE 37.

Maximum feedstock price scenario 1

RMP	MAX-FEEDSTOCK COST (USD/t)			
	250 KWE	1 000 KWE	10 000 KWE	50 000 KWE
<6	N.P.	N.P.	N.P.	N.P.
<28	N.P.	N.P.	N.P.	N.P.
<48	N.P.	N.P.	$3	$4
<51	N.P.	N.P.	$3	$4
<74	N.P.	$5	$9	$10

Note: The exchange rate used was 1 USD = 2.47 TL.

In order to contextualize the above results better, profitability zones maps were created. Profitability zones map for scenario 1 (Figure 57) was build based on a set of criteria obtained for scenario 1 (Table 37) and populated with values reported in Table 38. These last values were collected from different literature sources using international standard values in most of the cases (Polat, SelÇUk *et al.* 1993, DBFZ 2011, Agtech Centre 2013, Mou, Scheutz *et al.* 2014). Additionally, collection costs were calculated using the BEFS approach with specific Turkish parameters.

TABLE 38.

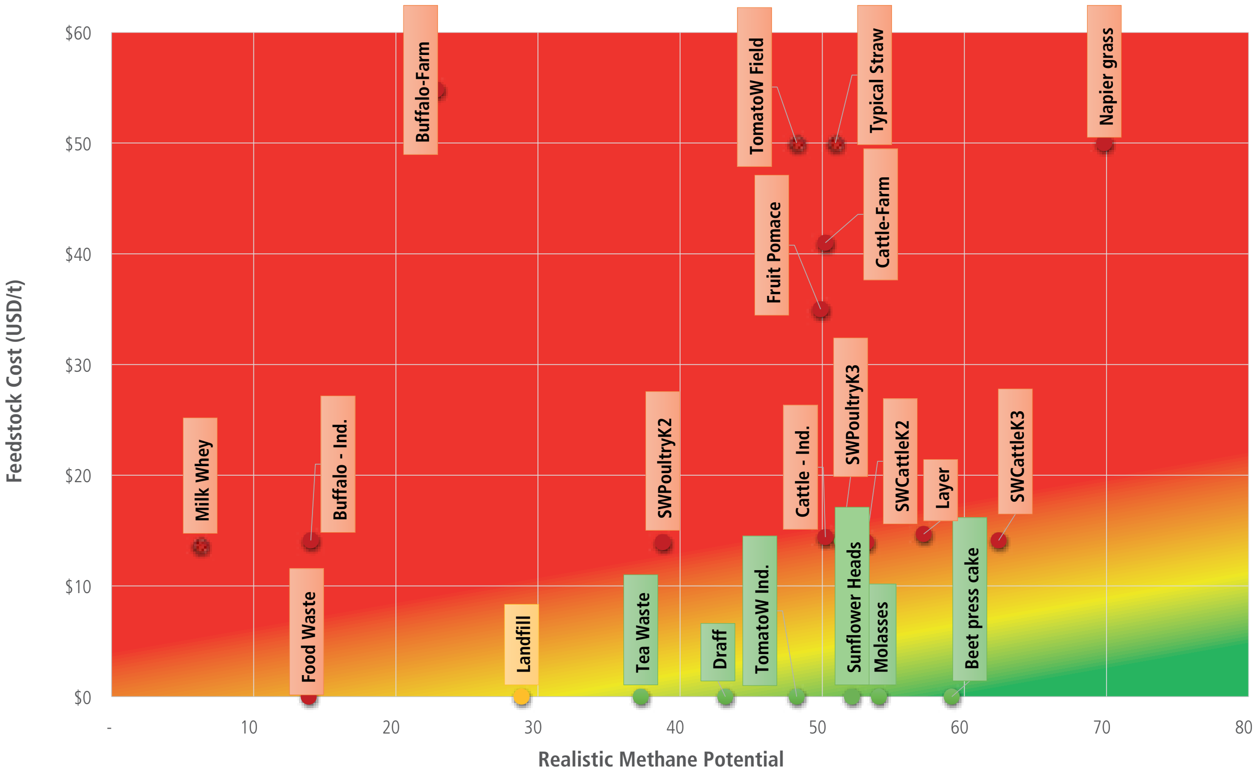
Standard biogas properties and estimated collection costs for selected biomass residues

	RMP	VOLATILE SOLIDS (%)	BMP	METHANE CONTENT (%)	TOTAL SOLIDS (%)	COLLECTION COST (USD/t)
Napier grass	70	89%	274	68%	33%	$50
SWCattleK3[1]	62	90%	400	60%	20%	$14
Beet press cake	59	95%	300	73%	24%	$0
Molasses	54	45%	308	73%	45%	$0
SWCattleK2[2]	53	84%	485	60%	15%	$14
SWPoultryK3[3]	51	96%	343	70%	18%	$14
Typical Straw	51	83%	170	60%	43%	$50
Cattle - Ind.	50	78%	250	65%	30%	$14
Cattle- Farm	50	78%	250	65%	30%	$41
Fruit Pomace	50	88%	189	68%	35%	$35
TomatoW Field	48	80%	200	60%	35%	$50
TomatoW Ind.	48	80%	200	60%	35%	$0
Draff	43	47%	503	57%	21%	$0
SWPoultryK2[2]	39	85%	350	60%	15%	$14
Tea Waste	37	76%	250	55%	23%	$0
Landfill	29	40%	206	65%	41%	$0
Buffalo - Farm	23	35%	230	65%	33%	$55
Layer	57	70%	243	65%	39%	$15
Buffalo - Ind.	14	35%	230	65%	20%	$14
Food Waste	14	25%	571	60%	11%	$0
Milk Whey	6	12%	1 000	65%	6%	$14
Sunflower Heads	52	68%	199	65%	45%	$0

Slaughterhouse wastes (SW), 1. Stomach/ Intestine (K3), 2. Content of Stomach/ Intestine (K2), 3. Blood (Poultry) (K3)
Note: The exchange rate used was 1 USD = 2.47 TL.

FIGURE 57.

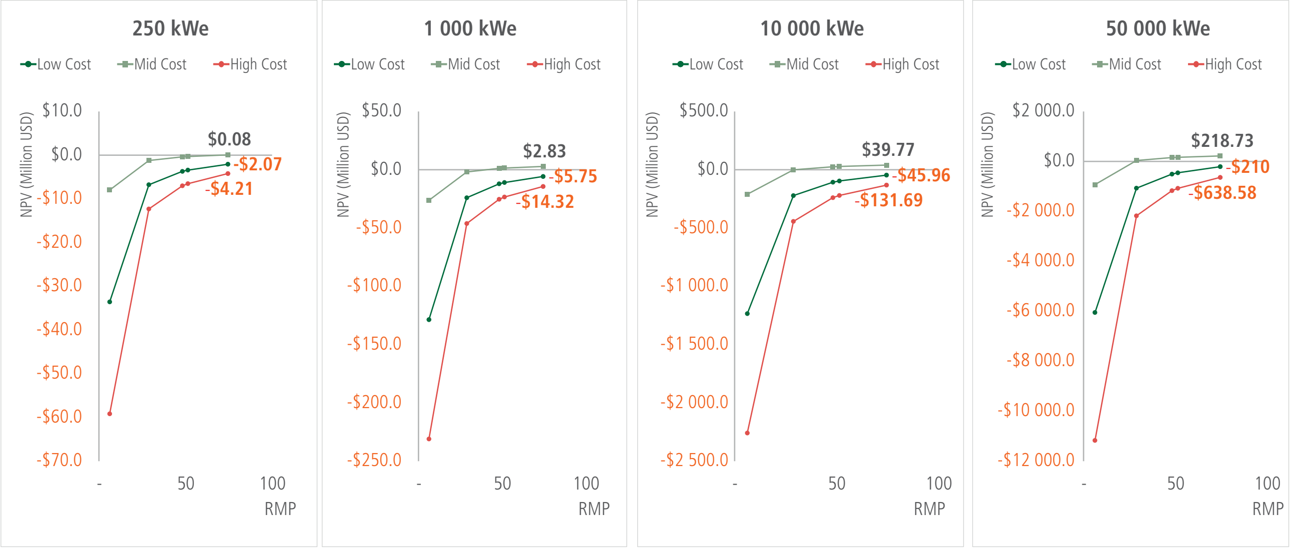
Profitability zones for scenario 1



Profitability zones map shows how under the current production conditions (feed-in tariff and heat cost) only those feedstock located in the green area would result profitable for biogas to CHP production, given their high RMP and/or relatively low cost. It is interesting to note, that the landfill option, which is most commonly used, would only be profitable for certain plant sizes and under specific conditions (yellow area). The landfill has freely available feedstock (municipal solid wastes, organic wastes, etc.) and they are paid to dispose of the residues, so they have additional credits that the other options do not have. However, the landfill option has a low RMP and therefore is not as competitive as other options, such as: teas waste and molasses.

FIGURE 58.

Combined profitability results for scenario 2



Results obtained for scenario 2 (feed-in tariff + premium + heat price) increased profitability to 30 percent (Figure 58). As a result, the price ceiling that might be paid for different feedstock was almost duplicated (Table 39). However, this change was not large enough to allow for the use of feedstock not locally produced in food processing plants attached to cogeneration facilities.

TABLE 39.

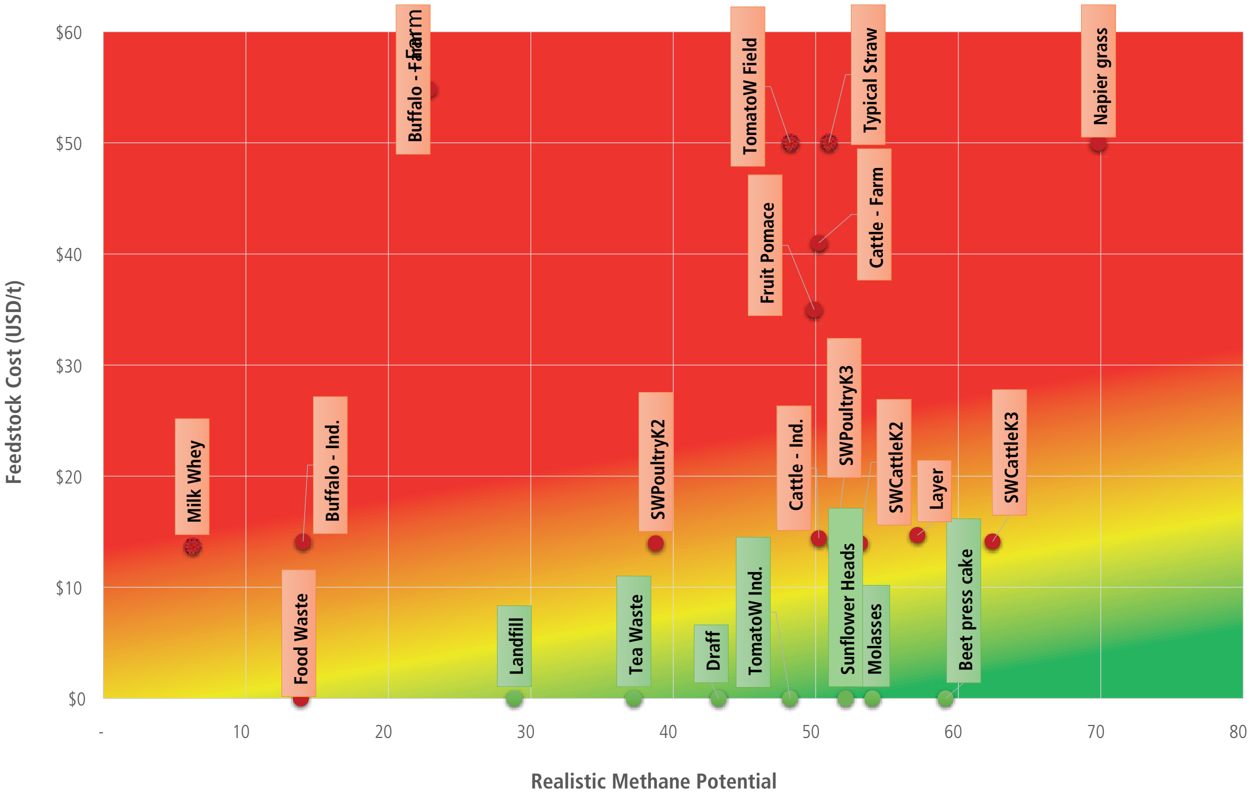
Maximum feedstock price scenario 2

RMP	MAX-FEEDSTOCK COST (USD/t)			
	250 KWE	1 000 KWE	10 000 KWE	50 000 KWE
<6	N.P.	N.P.	N.P.	N.P.
<28	N.P.	N.P.	N.P.	$1
<48	N.P.	$4	$6	$7
<51	N.P.	$4	$7	$8
<74	$3	$11	$15	$16

Note: The exchange rate used was 1 USD = 2.47 TL.

FIGURE 59.

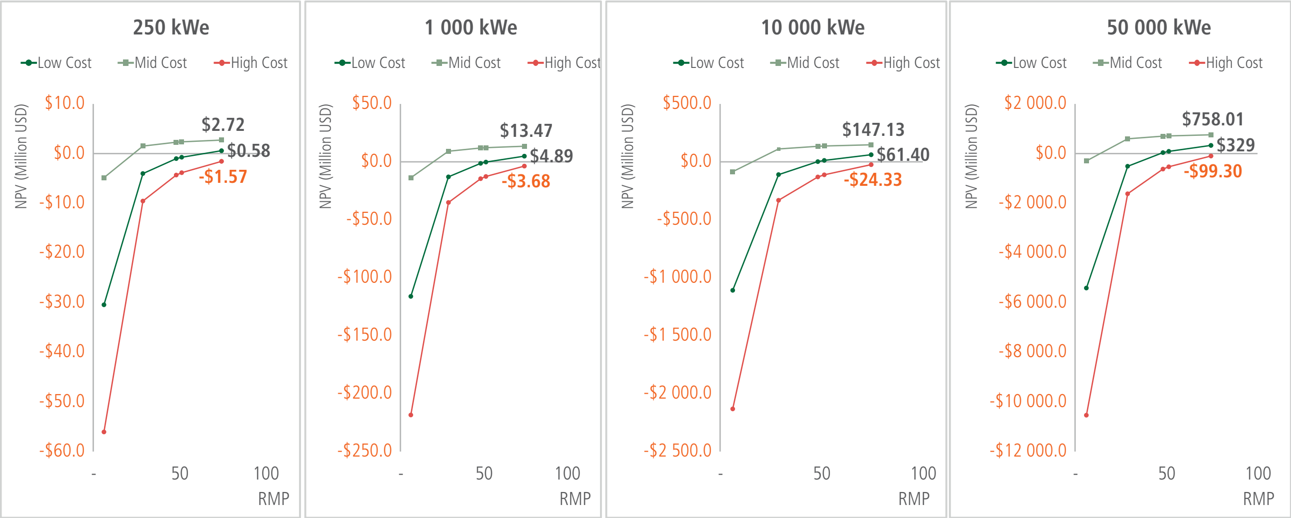
Profitability zones for scenario 2



Profitability zones map (Figure 59) shows how increases in profitability zones are minimal and only the landfill option was moved into the green area. Consequently, the number of feedstock that might be promising for biogas to CHP production are almost the same, although their production conditions were improved and more flexibility in feedstock prices might be allowed.

FIGURE 60.

Combined profitability results for scenario 3



Finally, in scenario 3 (feed-in tariff + premium + converting heat to electricity), profitability was increased 62 percent compared to scenario 1. This scenario would represent the best-case scenario with the ideal production conditions for Turkey. In this case, the operative change considered in scenario 3 increased the profitability. The effect of this change allowed for an increase in the number of feedstock that might be profitable (Figure 61) both at low and mid costs. Maximum feedstock prices were also increased, allowing for the payment of 50 USD/t even for the highest quality feedstock at large processing sizes (Table 40).

TABLE 40.

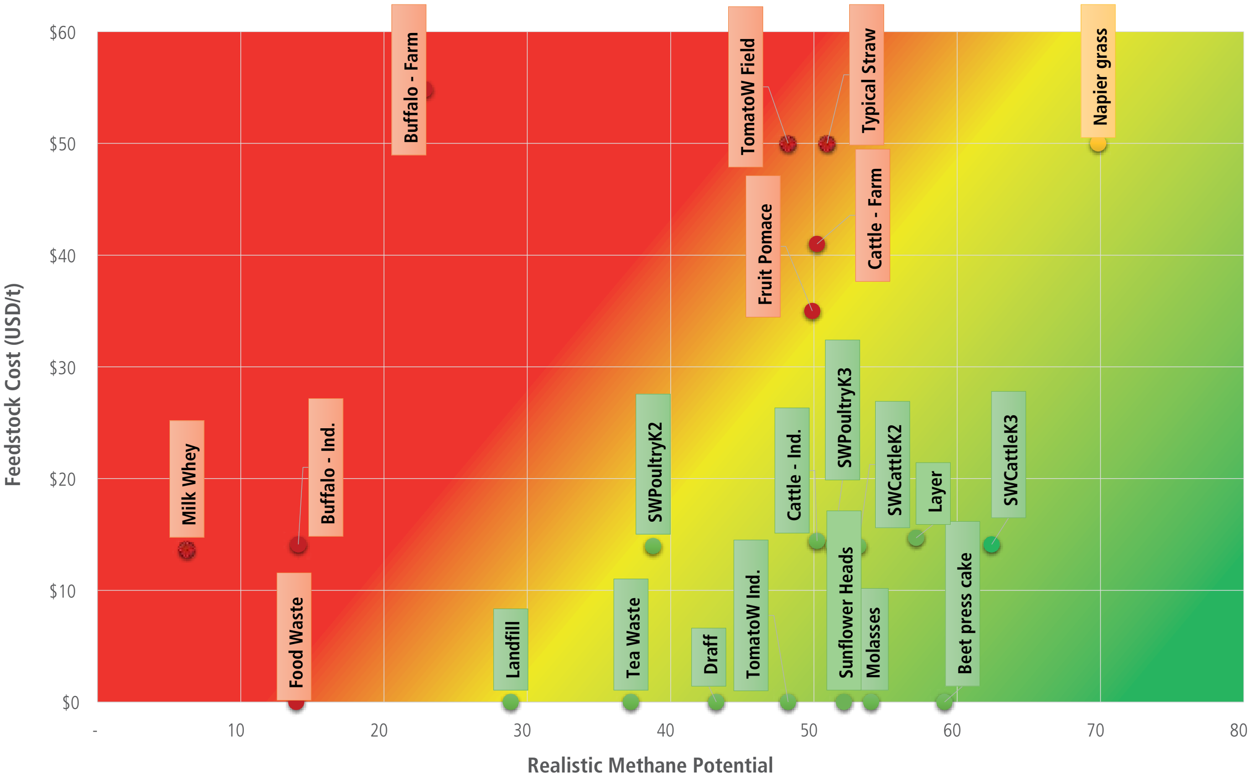
Maximum feedstock price scenario 3

RMP	MAX-FEEDSTOCK COST (USD/t)			
	250 KWE	1 000 KWE	10 000 KWE	50 000 KWE
<6	N.P.	N.P.	N.P.	N.P.
<28	$11	$14	$17	$18
<48	$24	$30	$33	$34
<51	$26	$32	$35	$36
<74	$43	$51	$55	$57

Note: The exchange rate used was 1 USD = 2.47 TL.

FIGURE 61.

Profitability zones for scenario 3



Profitability zones map (Figure 61) shows how under the best possible production conditions in Turkey, the green area has been largely extended including a larger number of feedstock options. In this group, it is possible to now find food-processing industry residues, manure collected at slaughterhouses and dairy plants, traditional residues such as landfill, and crop residues such sunflower heads.

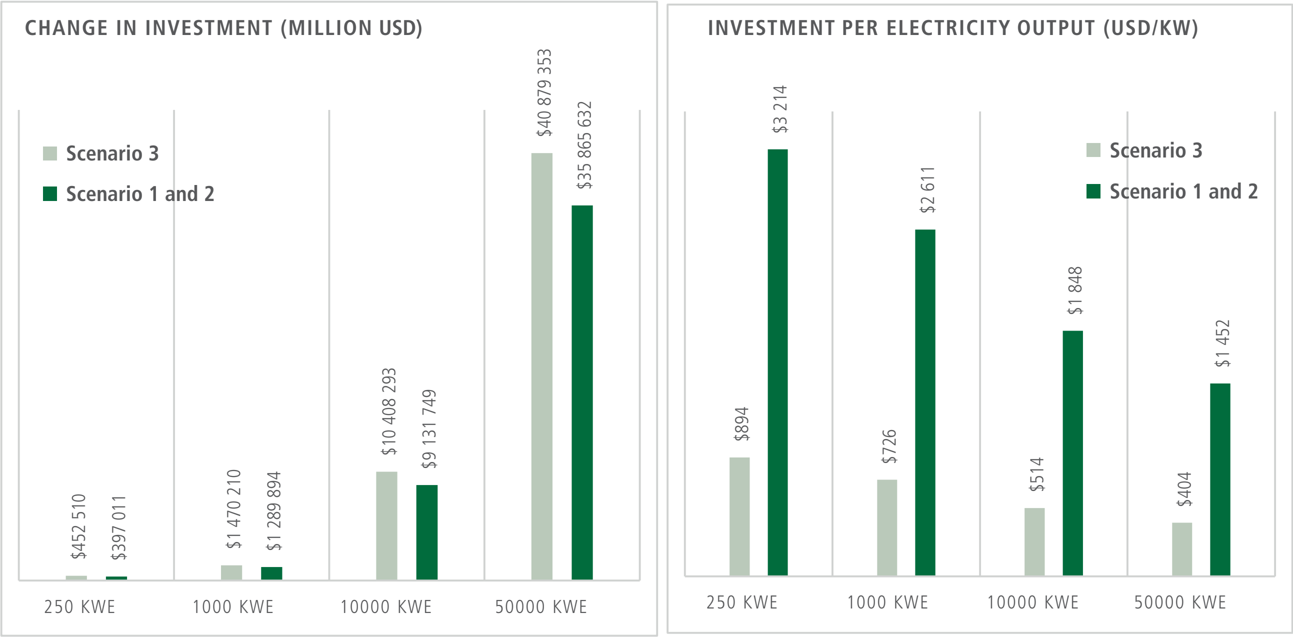
In summary, for CHP from biogas, it can be stated that the most competitive production scheme is similar to the one used in landfills where biogas is produced locally using freely available feedstock to generate massive amounts of heat and electricity. In particular, this includes food-processing residues, where a collection system is needed. It has been proven that it might be possible to support the expense required to establish a local collection system (flush system, vacuum scrapers, etc.). Moreover, the most interesting alternative for crop residues in Turkey was sunflower heads. Given the current collection costs, this feedstock might be successfully used in the country under the scenario 3 production scheme.

In the above results, in addition to the biomass potential identified in Natural Resource Assessment, cattle manure, poultry layer and sunflower heads were identified as promising and potentially available options for bioenergy production in Turkey. Techno-economic assessment allowed for the identification of these options as potentially profitable and competitive under scenario 3 production conditions. In this sense, it is important to understand what the implications are, in terms of investment and the number of consumers that might be supplied per scenario.

As it was explained for CHP from direct combustion, capital investment is a key factor in these kinds of projects. In the specific case of CHP from biogas investment, requirements are presented in Figure 62, considering differences in standard operation (scenarios 1 and 2) and modified operation (scenario 3). It can be noted how values for standard operation (blue bars) were in the same order of magnitude than those reported in the literature for CHP plants based on biogas, which was stated around 2 570-6 100 USD/kW (IRENA 2012). Conversely, the operative change considered in scenario 3 implies the conversion of all heat surplus into additional electricity, instead of selling it. This operative change requires an additional investment in terms of steam turbines that is presented as orange bars in Figure 62. Due to this, total capital investment increased for each plant size alternative. However, an additional electricity output was generated, reducing the unitary investment per electricity output to 1/3 of the standard value.

FIGURE 62.

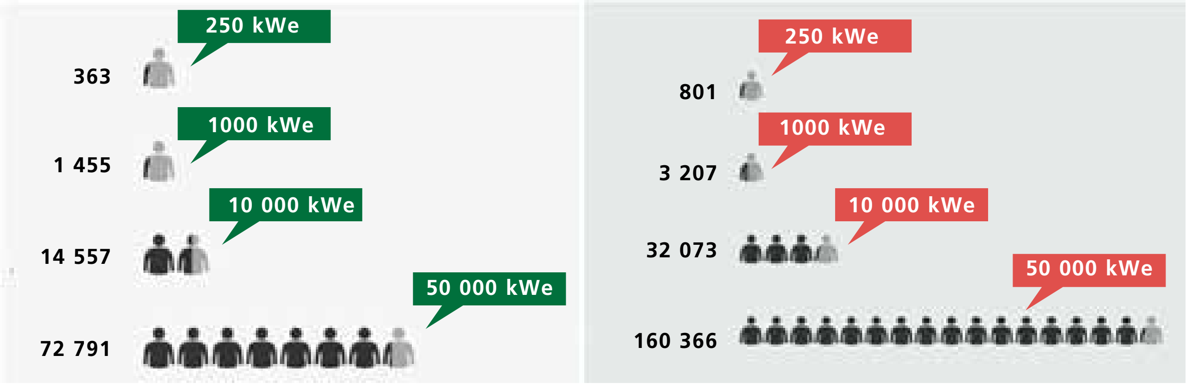
Comparison of capital investment for scenario 1, 2 and 3 in CHP from biogas



Finally, the number of households supplied for each plant size, comparing production scenarios, was calculated based on the heat and electricity demand for an average household in Turkey identified in the field data collection (Yaylacı 2015). The number of households that could potentially be supplied by each plant size used under different operative conditions is compared in Figure 63. It can be noted how the final number of consumers is duplicated converting heat into electricity.

FIGURE 63.

Comparison of number of households potentially supplied for scenarios 1,2 and 3 per plant size



Linking the above results with the Natural Resource Assessment, three of the most promising feedstock were selected, considering the criteria of feedstock availability, RMP and feedstock cost. Feedstock selected included: sunflower heads, cattle manure, and poultry layer. Then, based on the feedstock availability of these residues per province, the potential electricity production (using biogas to CHP technology) was calculated for those specific sizes identified as potentially profitable.

TABLE 41.

Potential electricity generation capacities of CHP system in provinces producing most promising residues

	ELECTRICITY CAPACITY (MW)			
PROVINCE NAME	BIOGAS FROM SUNFLOWER HEADS	BIOGAS FROM CATTLE MANURE	BIOGAS FROM LAYER MANURE	TOTAL CAPACITY PROVINCE (MW)
Konya	32.50	34.10	10.21	76.81
Edirne	39.60	6.00	0.21	45.81
Tekirdag	39.10	5.60	0.67	45.37
Kirklareli	25.60	8.30	0.32	34.22
Balikesir	4.80	19.30	5.80	29.9
Adana	18.30	9.60	0.70	28.6
Ankara	5.50	18.10	3.89	27.49
Afyon	-	11.50	11.66	23.26
Izmir	-	17.70	4.16	21.86
Bursa	4.30	10.50	3.85	18.65
Erzurum	-	17.40	0.18	17.58
Kayseri	0.60	12.70	3.46	16.86
Samsun	4.80	9.70	1.28	15.98
Diyarbakir	-	14.40	0.46	15.06
Denizli	6.20	6.70	1.63	14.53
Kars	-	14.30	0.20	14.5
Aksaray	8.00	6.20	0.28	14.48
Çanakkale	7.00	7.10	0.23	14.33
Manisa	-	5.70	8.36	14.06

ELECTRICITY CAPACITY (MW)				
PROVINCE NAME	**BIOGAS FROM SUNFLOWER HEADS**	**BIOGAS FROM CATTLE MANURE**	**BIOGAS FROM LAYER MANURE**	**TOTAL CAPACITY PROVINCE (MW)**
Aydin	-	13.40	0.60	14
Gaziantep	-	12.60	1.25	13.85
Eskisehir	5.10	4.80	1.15	11.05
Amasya	3.60	5.80	1.18	10.68
Corum	5.70	4.60	-	10.3
Mus	-	9.60	0.25	9.95
Istanbul	5.90	2.80	0.90	9.8
Sivas	-	8.40	0.44	8.84
Yozgat	-	8.10	0.63	8.73
Tokat	4.60	3.70	0.21	8.61
Kastamonu	-	8.00	0.23	8.23
Agri	-	7.40	0.14	7.54
Kahramanmaraş	2.20	4.70	0.28	7.18
Kirsehir	1.20	5.50	0.42	7.12
Ardahan	-	6.80	0.12	6.92
Mugla	-	5.60	0.51	6.11
Mersin	-	4.10	1.51	5.61
Van	-	5.10	0.32	5.42
Burdur	-	5.10	0.16	5.26
Igdir	-	4.40	0.10	4.5
Hatay	-	4.10	0.40	4.5
Kirikkale	0.70	3.20	0.59	4.49
Usak	-	4.30	0.15	4.45
Isparta	-	4.20	0.25	4.45
Nigde	-	4.00	0.41	4.41
Malatya	-	4.00	0.35	4.35
Kocaeli	-	3.80	0.55	4.35
Antalya	-	3.90	0.45	4.35
Karaman	0.80	2.40	1.12	4.32
Sakarya	-	3.10	1.21	4.31
Elazig	-	3.60	0.58	4.18
Trabzon	-	3.80	0.04	3.84
Kütahya	-	2.70	1.06	3.76
Erzincan	-	3.30	0.44	3.74
Ãankiri	-	3.70	-	3.7
Sinop	-	2.90	0.11	3.01
Mardin	-	2.60	0.37	2.97
Duzce	-	2.20	0.34	2.64
Adiyaman	-	2.40	0.21	2.61
Bitlis	-	2.40	0.07	2.57
Gümüşhane	-	2.40	0.09	2.49
Bolu	-	1.90	0.54	2.44
Bayburt	-	2.30	0.09	2.39
Bingöl	-	2.30	0.08	2.38
Giresun	-	2.10	0.02	2.12
Batman	-	1.90	0.15	2.05
Artvin	-	2.00	0.01	2.01
Nevsehir	-	1.30	0.71	2.01
Osmaniye	-	1.80	0.19	1.99

ELECTRICITY CAPACITY (MW)				
PROVINCE NAME	BIOGAS FROM SUNFLOWER HEADS	BIOGAS FROM CATTLE MANURE	BIOGAS FROM LAYER MANURE	TOTAL CAPACITY PROVINCE (MW)
Karabuk	-	1.70	0.23	1.93
Zinguldak	-	1.50	0.17	1.67
Ordu	-	1.30	0.22	1.52
Hakkari	-	1.00	0.04	1.04
Bartin	-	0.80	0.17	0.97
Sanliurfa	-	0.60	0.34	0.94
Tunceli	-	0.90	0.03	0.93
Siirt	-	0.70	0.08	0.78
Bilecik	-	0.40	0.20	0.6
Yalova	-	0.50	0.09	0.59
Kilis	-	0.50	0.08	0.58
Rize	-	0.40	0.01	0.41
Sirnak	-	0.30	0.06	0.36
Total Capacity Feedstock (MW)	226.1	460.6	80.3	

Considering the importance of dairy, poultry and sunflower industries in Turkey, there exists a huge potential in terms of these biomass residues. A potential conversion into biogas and then heat and electricity of these alternatives across the different Turkish provinces would be able to achieve a total combined production capacity of 768 MW. This value added to 244 MW predicted for CHP from direct residues reach a total combined production capacity of 1 012 MW of electricity. This amount would be enough to supply 101 percent the Turkish renewable energy targets for electricity production from biomass (Figure 64).

FIGURE 64.

Comparison of combined production capacity of CHP alternatives and Turkish renewable energy target for electricity from biomass

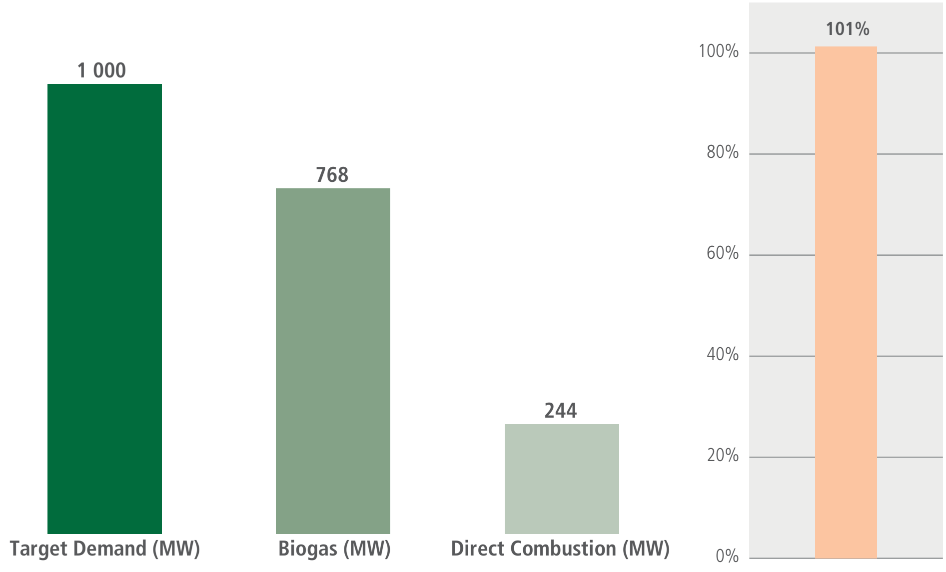
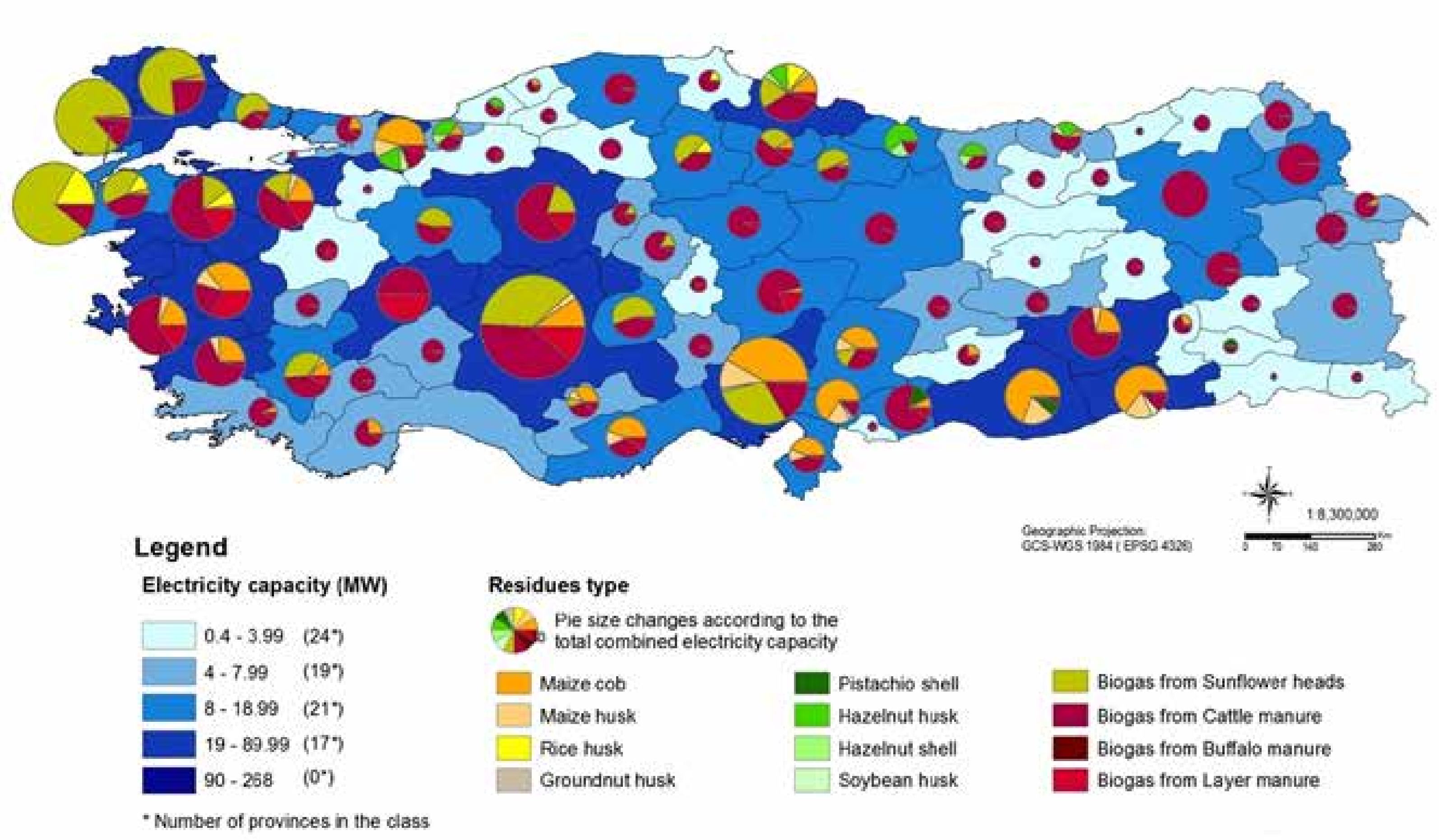


Figure 65 summarizes the target of 1 012 MW previously mentioned for the combined production capacity using the profitable combination of CHP technologies and selected biomass options. Thus, it can be noticed how the largest potential for electricity generation is located mostly in the Eastern and Southern parts of the country, where most of the biogas production to electricity would be located.

FIGURE 65.

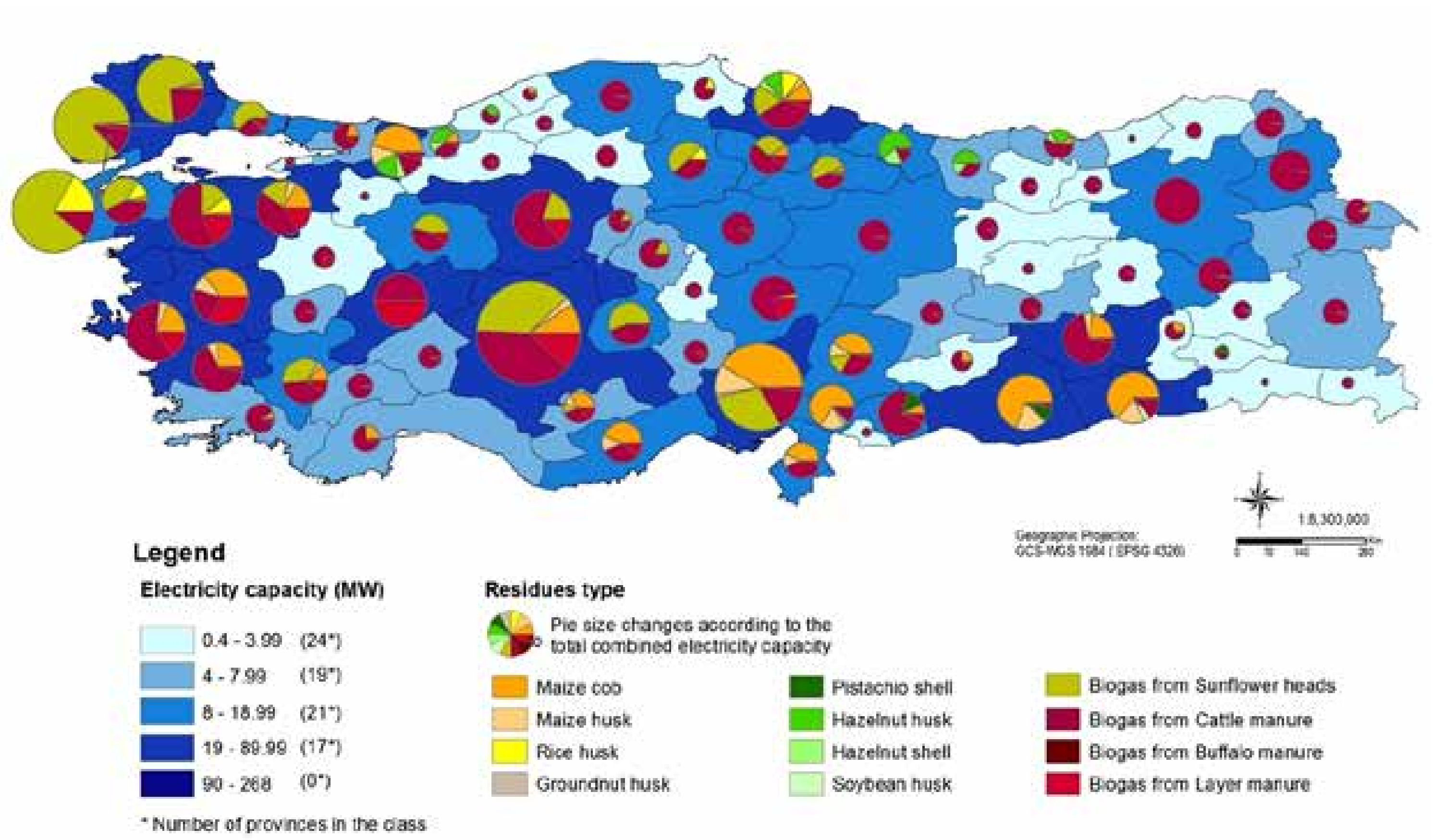
Electricity capacity generation (MW) from crop residues (excluding cotton stalk) and livestock manure biogas



In briquettes and pellets section it was discussed how cotton stalk feedstock would be a promising option once acessabitliy levels for this feedstock would be increased. Another potential use of this feedstock would be as fuel for CHP direct combustion systems. In this sense, inclusion of cotton stalk under an assumed accessability level of 35 percent, it would be possible to raise total combined production capacity to 1 600 MW. Additionaly, inclusion of cotton stalk residue would change the order of importance on terms of electricity production for Turkish regions, increasing the interest on Southern Anatolia provinces (Figure 66). These results are a good indicator of the importance that cotton stalk might have for the future development of bioenergy in Turkey, considering its potential high availability, collection cost and energy potential.

FIGURE 66.

Electricity capacity generation (MW) from crop residues (including cotton stalk) and livestock manure biogas



Overall based on above results it can be stated that biomass based CHP in Turkey will have as key players biogas production facilities attached to slaughterhouses, and dairy industries in Marmara, Aegean and Central Anatolia, while direct combustion from crop residues would be a promising option for Southeast Anatolia.

CONCLUSIONS

Briquettes and pellets

- Under the context of the BEFS assessment, briquetting and pelletizing biomass would be promising options to support the achievement of the renewable energy production targets of the country. All these, under a set of specific production conditions and feedstock options, would make these industries profitable and attractive for investors.
- BEFS techno-economic analysis was able to identify the production conditions that would make briquettes and pellets production profitable. First, It was identified 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 obtained results also indicate that pellet production would result more profitable at medium and large plant sizes (i.e. larger than 400 kg/h), while briquette production might be profitable at all plant sizes. Consequently, profitable pellets industries would require a comparatively larger investment than briquettes factories, although they would be able to generate larger revenues.
- Briquetting and pelletizing can be considered as efficient technologies that help to extract in a more efficient way the energy potential contained in biomass residues with no specific chemical transformation of materials. Then, the product that essentially is being sold is biomass in a densified form that might be used as replacement option for fossil fuels or as an alternative for already established briquettes and pellets produced from coal or fuelwood.
- 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. In this sense, for regions where biomass briquettes would replace coal, producers should use feedstock with an energy potential larger than 15 MJ/kg and the price ceiling might reach 60 USD/t. Conversely, in regions where biomass briquettes would replace fuelwood, the minimum required energy potential is 13 MJ/kg and price ceiling would reach 250 USD/t. Therefore, it is advisable to promote biomass-based briquettes and pellets in those provinces with high fuelwood consumption or deforestation problems.
- In the first case, where biomass briquettes and pellets would be competing in provinces with already established industries (e.g. Samsun province), it was found that the minimum energy potential 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 75 USD/t (briquettes – all scales) and 150 USD/t (pellets – large-scale).

- Based on the above set of conditions, the top 10 most promising crop residues that were identified as potentially available and that might result profitable under the Turkish conditions include: 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 support the achievement of Turkish Energy Targets was illustrated using the cotton stalk example. Considering the amount of cotton stalk that would be available for bioenergy, briquette/pellet industries could be established in more than 20 provinces of Turkey located in the Aegean, Marmara, Mediterranean, and Southeast Anatolia regions. The combined energy output obtained, accessing a 20 percent of the cotton stalk, was identified as 1 033 ktoe. This would supply an important share of the Turkish renewable energy target of 3 537 ktoe. Moreover, the potential energy output might reach 2 589 ktoe, if cotton stalk accessibility would be increased to 50 percent. This potential obtained for cotton stalk is only an indicator of the role that bioenergy might have to meet the renewable energy targets of the country and how measures to support and increase the accessibility of biomass residues would in turn result in greater energy independence for Turkey.

Cogeneration of heat and power

- Cogeneration of heat and power is an efficient form to extract the energy contained in biomass and upgrade it into a more useful from of energy such as heat and electricity. In the BEFS techno-economic analysis, three technology variations were analysed. These variations were featured by improvements in efficiencies, but also by increases in capital investment and operation costs.
- As result of this assessment, under current Turkish conditions (prices, capital investment, tariffs), a set of profitable production conditions was defined. First of all, CHP plants should operate using high efficiency technologies, preferring high-energy potential feedstock. Due to the lack of a massive heat distribution infrastructure, there were uncertainties in the actual price of heat and therefore assessing the profitability of combined heat production was inaccurate. Considering this, electricity should be the main product of CHP plants.
- Finally the best production scheme (stand-alone/attached) will depend also on feedstock location and price. Thus, feedstock located at processing plants should be used in attached production schemes and should sell electricity to the central grid (heat is transferred to the processing plant). Conversely, feedstock located in the field should be in stand-alone production schemes and convert heat into electricity and sell this electricity to the central grid (higher capital investment).
- The BEFS techno-economic analysis considered two feedstock options based on the optimum transformation route that the Turkish agro-industrial residues might have, considering their particular features and location. Thus, it was possible to distinguish biomass residues burnt directly in CHP plants (crop residues mainly) and residues

that needed to be converted into biogas first, before being used in CHP plants (manures mainly).

- Profitability under Turkish conditions was assessed considering the current feed-in tariff defined for electricity production from renewables, specifically from biomass as 0.133 USD/kWh with a maximum premium of 0.056 USD/kWh, under a set of specific production conditions. Results of the BEFS analysis showed that the defined feed-in tariff would be enough (under certain operation conditions) to grant a profitable operation both for feedstock burnt directly in CHP plants as for feedstock converted to biogas first, fulfilling certain conditions in terms of energy potential and price. In the first case, it was found that feedstock used to be burnt directly in CHP plants should have energy potentials larger than 13 MJ/kg with an average price ceiling of 50 USD/t. This price ceiling might be increased to 68.5 USD/t in the case that all production premiums are accessed, and a feed-in tariff of 0.189 USD/kWh could be reached. On the other hand, for feedstock converted to biogas first, these should have a RMP ranging 30-70 with a price ceiling 35-70 USD/t.
- Feedstock fulfilling the above technical conditions and identified as available for bioenergy production in Natural Resource Assessment were: direct residue combustion from groundnut husk, pistachio shell, hazelnut husk, rice husk and potentially from maize cob and maize husk along with biogas to CHP from cattle manure, poultry manure and sunflower heads. Using these identified feedstock across different provinces in the country, it would be possible to reach a combined production capacity of 1 012 MW. This production, compared to the 1 000 MW defined as the projected energy production from biomass by 2023 in Turkey, would allow the country to meet 101 percent of their target.
- In conclusion the results show that there is significant potential for biomass to contribute renewable energy targets in Turkey, using potentially profitable technologies to transform sustainable biomass.

CHAPTER 4

POTENTIAL AGRO-PROCESSING RESIDUES IN TURKEY

THE AGRO-PROCESSING CHAIN AND AGRO-PROCESSING RESIDUES

The processing of agriculture produce into value-added products is a key component of agricultural value chains. Processing fruits into jams or oilseeds into vegetable oils are two examples of common food processing systems. Along with the intended final product, food processing also produces other organic residues and by-products. The key distinction between a residue and a by-product is the fact that by-products can be used as valuable inputs into other processes while residues do not have other identified productive uses. A residue produced in an agro-processing plant therefore could be used as a feedstock for energy production without competing with any other sector as they are by definition unused. The potential of a residue to be used for bioenergy production depends on its chemical and physical properties as well as its availability. Turkey has a large agriculture sector and related food processing industries. Given this, there was interest in understanding if there might be unused residues available for energy production within the agro-processing chain. A small questionnaire was developed including a specific set of questions to ascertain what amounts and types of residues might be available within the industry. It is important to note that this information is not always easy to obtain and therefore these efforts provide some initial insights into the actual potential. Some of the companies that participated in the questionnaire screening expressed interest in a more detailed screening process, which would allow for a more realistic estimation of the potential on a case-by-case basis.

Agro-processing groups and structure of the questionnaire

The assessment of the availability of agro-processing residues was carried out through a short questionnaire conducted among agro-food and wood processing facilities. The results obtained from the questionnaires were then aggregated for further analysis. The first step was to identify types of industries whose residues are suitable for heat and/or power generation through direct combustion, biogas and/or CHP technologies.

The industries were classified into three categories and each processing facility was then linked to one of those (Table 42):

- food processing
- livestock and chicken production and processing
- wood processing

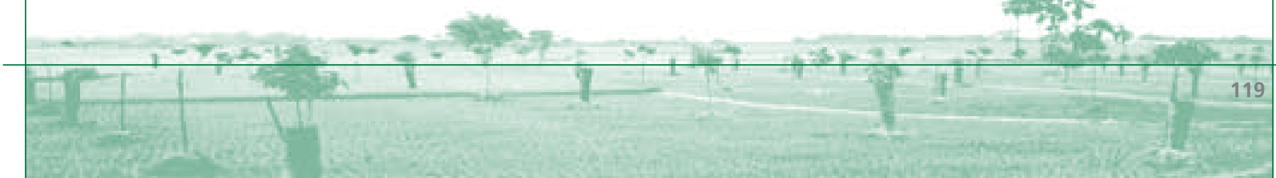


TABLE 42.

Industries targeted by the questionnaire

FOOD PROCESSING	LIVESTOCK AND CHICKEN PRODUCTION AND PROCESSING	WOOD PROCESSING
Fruit and vegetables	Dairy farms	Saw wood
Oilseeds and vegetable oil	Cattle for meat	Fuel wood
Sugar, syrup and ethanol production	Bull breeding	Pellets
Beverages and breweries	Egg chicken (layers)	Briquettes
Milling	Meat chicken (broiler)	Wood chips
Milk and dairy processing		Veneer sheets
Meat processing		Plywood, particle board
Fish processing		Pulp, paper and packaging
Tea and coffee processing		Furniture
Tobacco processing		

The questionnaire was carried out in close collaboration with the General Directorate of Agricultural Research (TAGEM) under the Ministry of Food, Agriculture and Livestock (MoFAL). Initially, TAGEM identified more than 1 000 companies operating across the country that could participate in the questionnaire. The list of agro-food processing companies was retrieved from the TAGEM and MoFAL database and clients of European Bank for Reconstruction and Development (EBRD), while the Ministry of Forestry and Water Management provided the list of wood processing companies.

A minimum of 10 companies were selected within each subgroup and the selection was done in close collaboration with TAGEM, which provided key inputs on the relative size and importance of companies in their respective industries. Based on this, 500 companies were selected and contacted to respond to the questionnaire. TAGEM carried out the questionnaire and contacted the companies.

A specific questionnaire was developed for each of the three industry groups and within each one, information on the specific production systems and respective processes was collected. The structure and basic content of the three questionnaires were the same, but each specific questionnaire type captured differences across the industries.

The questionnaires included four sections:[16]

3. **Company information**. This dealt with the basic company information, its main products and production capacities;
4. **Solid residues**. The type and amount of solid residues generated, and the manner of their utilisation and/or disposal;

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[16] The participants were informed that the information obtained through the questionnaire would remain confidential and would be aggregated according to the industry groups, to be used for the analysis. Nevertheless, they were invited to support the analysis and be a model for the case studies. A respective consent form for the use of information was included in the questionnaire.

5. **Wastewaters**. Companies were asked to provide information about the amount and characteristics of the generated wastewaters, including if and how they are treated before being discharged;
6. **Energy demand and production**. This section focused on the energy needs for processing, also asking if the company had considered using combined heat and power (CHP) technologies for the production of energy on-site.

A first round of questionnaire was conducted between February and March 2015. Of the 500 questionnaires sent, 120 companies returned the filled-in questionnaire to TAGEM. The final gathered responses are listed in Table 43. Some of the companies that responded to the questionnaire also gave their consent to be in a case study.

TABLE 43.

Distribution of questionnaire responses by industry

TYPE OF INDUSTRY	TYPE OF PROCESSING FACILITY	NO. OF RESPONDENTS
Food processing	Tea factories	36
	Sugar factories	26
	Other food processing (mainly dairy and beverage)	18
Livestock and chicken production	Cattle and chicken meat production	31
Wood processing	Wood processing factories	09
Total		120

The responses from the companies left some key questions unanswered, especially regarding the way residues are currently utilised or disposed. Due to this, a second iteration of the questionnaire process was carried out between January and February 2016. The main dimension of this second round was to understand the current use or disposal practices of residues, since it is directly related to the This was important since the availability of residues for bioenergy production is directly related to their. During the second round, the companies that had missing/unreported data were contacted so that this information could be gathered. In total, 45 tea-processing factories, 24 sugar factories, 9 dairy processing plants and the 31 cattle and poultry farms were contacted. However, of the 31 cattle and poultry farms only TAGEM could only get data from 11 livestock (7 cattle and 4 poultry) farms as the remaining either refused to participate in the questionnaire or did not furnish the requested data.

The second round of questionnaires were followed by a field visit in the provinces of Samsun, Giresun, Ordu and Rize in the Central Black Sea region. The purpose of the field visit was to better understand the residue management practices and verify the availability of residues for bioenergy production. Samsun was visited as it is the major rice producer, whereas Ordu and Girasun were visited because they are the major hazelnut producing regions. Lastly, Rize was visited as it has the largest tea industries in Turkey.

Indications from the questionnaires

Overall, the results indicate that certain residues from sugar production, dairy processing and other food processing (jams, juices, etc.) are technically suitable and available to be utilised for energy production. Additionally, although the results of the questionnaire indicate that tea-processing residues are generally given away to the farmers for free, this may not always be the case. In fact, in some cases, tea-processing residues may also be available for the production of bioenergy.

The summary of the results is provided in Table 44. A more detailed industry-specific discussion of the results is provided after the table.

TABLE 44.

Summary of results

INDUSTRY TYPE	MAIN RESIDUE TYPES RESIDUES	INDICATION OF RESIDUE AVAILABILITY FROM THE QUESTIONNAIRE	REMARKS
Tea processing	Dry tea leaves and stems	Not available	Although the questionnaire results indicate that most residues are not available for bioenergy and are given to the farmers for free, this may not always be the case. During the field visit in May, a tea factory in Rize explained that they were currently storing the residues within the facility and planning to produce heat and electricity from these residues. This was also to avoid problems with production of low quality tea.
Sugar production	Filter mud, clinker, bagasse and syrup	May be available	Mud that is generated during the raw sugar production process is technically suitable and available to produce biogas. Bagasse and syrup are key by-products that already have a market and hence are not available for bioenergy production.[17]
Dairy processing	Packaging material, defected products, products returned after expiry date.	May be available	The defected products and expired products are technically suitable and may be available to produce bioenergy. However, further study is required to understand the actual availability and economic viability of using these residues for bioenergy production.
Poultry meat and egg production	Manure, broiler bedding	Not produced at the processing plant	Information about these residues was not available at the processing plant level as most companies buy meat and eggs directly from sub-contracted farmers and slaughterhouses.

INDUSTRY TYPE	MAIN RESIDUE TYPES RESIDUES	INDICATION OF RESIDUE AVAILABILITY FROM THE QUESTIONNAIRE	REMARKS
Other food processing factories (non-alcoholic beverages, fruit and tomato juice factories)	Packaging material, defected products, products returned after expiry date.	May be available	The defected and expired products are technically suitable and may be available to produce bioenergy. However, further study is required to understand the actual availability and the economic viability for the residues to be used for bioenergy production.
Wood processing factories	Various woody residues like wood shavings, saw dust, tree bark, etc.	Not available	The wood processing residue are high value products and all residues produced during wood processing are used for other purposes. These include furniture manufacturing and chicken bedding.

Tea Factories[17]

The majority of the tea factories are operated by the governmental authority named Çaykur. The residues are managed in a similar fashion in these factories. In the questionnaire responses, most tea factories reported that the residues are given away to the farmers to be used as soil amendment. However, during the visit to the Caykur facility in Rize, it was discovered that tea companies are indeed exploring ways to use their residues to produce energy, intended either to be sold to the grid, or to be used within the processing plant.

The change in residue management practice is partly due to the fact that tea residues can potentially be sold as low quality tea. Tea residues contain the same extract that gives tea its colour and flavour, and therefore could potentially be sold as low quality tea by third parties. This issue was raised by the representatives of both private and public sector tea factories during the field work meeting in Rize. The Caykur factory in Rize that was visited during the field trip already collects the residues and has developed a plan to set up 4 energy production facilities with a capacity of 1 MW each. Another tea processing company, Doğus, already generates electricity and heat by using its own residues as well as the residues generated in the neighbouring tea factories.

Among the tea factories analysed, 32 percent become operational within the last week of April and 68 percent of the tea factories start the operations by mid-May. All of the tea factories are operational until October. Thus, tea-processing factories are operational five months within the year.

The main tea processing residues are tea stalk, tea fibre and caffeine dust. According to Çaykur, 5 percent of the fresh tea leaves that are fed into the production line become residues. The harvested tea has 75 percent moist and 25 percent of solid matter. Two of tea factories also provided the low heating value (LHV) of the residue to be around 16.7 MJ/kg. However, other tea factories did not provide data for this.

All the tea factories that participated in the questionnaire indicated that electricity, heat and steam are used in tea processing. Thirty-one percent of the companies questioned

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[17] However, one private sugar factory that participated in the questionnaire indicated that bagasse and syrup was used to produce electricity and that heat was consumed within the factory.

indicated the steam pressure used to be around 5 Bar, 23 percent of the companies used 6 Bar of steam pressure, while only 1 factory used 10 Bar pressured stream for the process. Fifty-nine percent of the factories did not provide information about the stream pressure. Sixty four percent of the factories indicated that only coal or fuel oil is used as the energy source for producing heat and steam. Around eighteen percent of the factories also use either electricity, natural gas or fuel oil as along with coal within the processes. Eighteen percent of the factories did not provide information about the fuel type.

Sugar Factories

Similar to tea factories, the majority of the sugar factories in Turkey are owned and operated by the government. Türkiye Şeker Fabrikaları A.Ş., which is the general directorate of the sugar factories in Turkey. The general directorate was contacted and was requested to reply to the questionnaire.

Most sugar factories in Turkey work between September and January. Hence, these factories are operative approximately 100-120 days/year and therefore this is period is when most residues and by-products are generated. The main residues and by-products produced are bagasse, syrup, mud and wastewater. Bagasse and syrup are valuable by-products, which are generally used as feed for animals or sold to producers of alcoholic beverages or yeast.

Coal and natural gas are the main fuels used to produce heat, while electricity is either bought from the grid, or is produced within the facility through coal/natural gas.

The second round of questionnaires were filled in by the Türkiye Şeker Fabrikaları A.Ş., based on 19 of its factories. This questionnaire stated that wastewater was the most produced residue followed by bagasse, mud and syrup (Table 45).

TABLE 45.

Most produced residues in government-owned sugar factories

RESIDUE	AVERAGE SHARE IN TOTAL RESIDUE PRODUCTION
Bagasse	27%
Syrup	4.4%
Mud	6.8%
Wastewater	61.8%

While bagasse and syrup are ideal feedstock for biogas production, they do already have a market and are used for other purposes, as mentioned above.[18] The wastewater is collected in ponds and is processed further to separate the solid fraction (mud) from liquid. The liquid is then reused within the facility and hence, it is not available for bioenergy production.

The mud obtained after the wastewater has been processed is available and consists of proteins, fibres from the bagasse, and traces of sugar, which makes it appropriate for

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[18] Nevertheless, there are sugar factories that are operated by the private sector which use bagasse to produce electricity and heat. The substrate obtained after the production of energy is then given to the farmers and is used as fertilizer. Hence, the use of bagasse for bioenergy production would need to be determined on a case-to-case basis.

bioenergy production. However, further analysis of its chemical composition may be required since the actual content of proteins, fibres and sugars can vary significantly from factory to factory.

Dairy Processing

Similar to the meat processing industry, almost all the milk companies sub-contract farms, which produce milk and then sell it to the dairy processing plant. This is a common business model in the sector. Therefore, the majority of the companies that replied to the questionnaire did not have information on the production and use of cattle manure.

The primary residues produced at the dairy processing plants are composed of packaging material and products that have passed their expiry dates. Most companies that replied to the questionnaire expressed that the expired products are either given for free, or are sold to the waste management and disposal companies.

However, one of the companies that produces yogurt and ayran (a milk-based beverage) mentioned that they use the expired products and sludge obtained after the wastewater treatment to produce electricity. This supplies approximately 25 percent of the electricity used in its facility in Anksaray (Table 46).

Therefore, the defected and expired products may be available to produce bioenergy. However, a detailed study is required to understand the actual availability and the economic viability of using these for bioenergy production.

TABLE 46.

Example of a sugar factory using residues for energy production

RESIDUE	AVERAGE ANNUAL AMOUNT (TONNES/ YEAR)	PERCENTAGE OF TOTAL RESIDUES	FINAL USE
Defected or returned products	12 930	38%	Electricity generation
Water treatment sludge	7 200	21%	Electricity generation
Hazardous waste	78	0.2%	Given to licensed company
Scrap waste	3 940	12%	Given to licensed company
Municipal waste	9 944	29%	Given to licensed company

Poultry meat and egg production

Similar to dairy farms, large poultry processing factories sub-contract chicken producers who in turn raise and feed the chickens and sell the eggs to the company. Therefore, information about the production and availability of chicken manure is difficult to attain from the processing facilities. Additionally, the sub-contracted farms are generally located across provinces and regions and therefore even when the number of animals indicated by the company in the questionnaire is large, the accessibility to these farms is a challenge.

For instance, a broiler production facility located in Beypazarı/Ankara has subcontracted farms in the following provinces seen in Table 47.

TABLE 47.

An example of sub-contracted chicken farms and their location

LIST OF CONTRACTED FARMS		
Location	Number of farms	Total capacity
Ankara	55	2 455 500
Bartın	11	588 100
Bolu	341	852 509
Çankırı	19	1 058 400
Düzce	141	3 216 400
Eskişehir	1	22 500
Karabük	13	370 900
Kocaeli	17	178 100
Sakarya	35	1 152 900
Zonguldak	146	3 532 300

Additionally, chicken manure and bedding have competing uses and in many cases the poultry farmers sell the manure/bedding to the local farmers for about 16.19 USD/ton.[19] Therefore, besides the accessibility, availability should also be considered for further studies, as there is already a market for chicken manure.

Meat processing companies

The meat-processing sector has a similar business model as the poultry and dairy producing companies. The large meat companies subcontract livestock farmers and slaughterhouses, which raise and slaughter the animal and sell the meat to the meat processing company. The processing company then packages and sells the meat. As a result, the main residues produced at meat processing level are packaging material and non-hazardous solid waste that are managed or disposed through private waste management companies. This type of business model generally also applies to the large-scale companies that exist at national level such as Apikoğlu (etsan Gıda Sanayi A.Ş.), that do not own livestock farms and purchase the meat from the market.

There are, however, a few large companies such as Pınar Et and Namet that own livestock farmers in different provinces of Turkey. However, of all the large companies that own cattle, only Pınar Et, took part in the questionnaire. The information provided by the company proved to be very limited due to the fact that Pınar Et was undergoing a

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[19] Assuming 1 USD= 2.47 TL

restructuring program, so their cattle farms were not in full operating conditions and it was not possible to provide precise details of the residue management practices.

Considering the meat processing industry structure and given the type of residues, there is limited scope for bioenergy production from residues in this industry group. The larger scale companies that own and rear their own livestock may be an exception and bioenergy production may be feasible.

Other food processing factories

The questionnaire conducted with the food processing factories also included non-alcoholic beverages and other types of agro-processing facilities, such as fruit and tomato juice factories. The residues of these facilities are similar to dairy processing facilities and include packaging materials and defected or expired products. The production facilities pay waste management companies to dispose of these residues. However, similar to the dairy processing residues, the defected and expired products may be suitable to produce biogas, given their organic origin. However, further analysis is required to understand the actual availability as well as the economic viability to use these residues for bioenergy production.

Wood processing factories

The list of wood processing factories to be contacted was determined based on the company list provided by the Ministry of Forestry and Water Works. The list included only those companies, which processed more than 10 000 m^3/year of wood in 2014. It was found that almost all the residues produced during wood processing are used for other purposes. These purposes include their use in the furniture manufacturing industry as well as use in the poultry industry where wood shavings are used as bedding for broilers.

From the field visit to poultry farms, it was understood that wood shavings were in high demand and were difficult to find in the market resulting in rice husk being used as broiler bedding. Two poultry farmers that were interviewed explained that even though they preferred wood shaving as bedding for broilers, they were forced to buy rice husks due to unavailability of wood shavings in the market. Therefore, the potential to use wood processing residues for bioenergy production seems limited in Turkey.

RECOMMENDATIONS AND POTENTIAL NEXT STEPS

Although not comprehensive, the results of this questionnaire, along with the field visit, indicate that certain residues from sugar production, dairy processing, tea processing and other food processing (jams, juices, etc.) may be available to be utilised for energy production. Nevertheless, further investigation is required to explore the technical as well as economic viability of using these residues for bioenergy production. It is also important to note that residue management practices can vary across processing plants and hence a more industry-focused assessment would be required. This initial questionnaire exercise provides a first indication towards which agro-processing industries should be targeted for further examination.

A potential way forward could be to identify and develop partnerships with agro-processing plants within these sectors. At the time when the questionnaire was sent to companies, some companies stated they would be interested in being case studies for this type of analysis. Therefore, companies that have already expressed interest in being involved in any such activity could be the first ones to be contacted. This could be done by identifying the major regions where the identified agro-processing industries are located and conducting a more comprehensive assessment of the availability of the identified residues.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Smart energy use begins with a clear identification of the specific energy forms required by consumers (e.g. communities and industries) according to their particular energy demands. Given this, the most promising and interesting markets can be determined, and sustainable bioenergy can effectively replace non sustainable energy forms. This primary strategy, combined with local biomass potential assessment, can help pinpoint the location of suitable sites for bioenergy plants as well as define the energy that could be generated from biomass. The potential to convert biomass residues into more efficient fuels such as briquettes and pellets or alternatively directly produce heat and electricity using CHP (i.e. cogeneration of heat and power) was the main focus of the assessment.

The assessment illustrates that there is potential to generate energy from agricultural residues in Turkey, with the aim to reduce dependence on and substitute away from fossil fuels. The first phase was to calculate the biomass potential and the second phase was to define the profitable production conditions. The CHP analysis provides an initial indication on the type of CHP set up that would be most effective given the combination of different technical criteria. Attached CHP plants that are locally supplied with residues obtained from a processing facility are better suited in more industrialised zones of the country that have specific steam and electricity demands. Whereas, stand-alone CHP plants selling heat to nearby communities are more suitable in provinces with already existing district heating networks. The stand-alone plant could also make additional investments that would allow for the conversion of heat into cool via a cooling system (i.e. absorption chillers), granting a year-round market. 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 policies in place (i.e. feed-in tariff). The CHP results illustrate that agriculture residues might fully meet the 1 000 MW biomass electricity capacity for renewable energy by 2020. For briquettes and pellets, the assessment indicates which options are feasible in which specific areas depending on the specific energy demand requirements and biomass availability. More specifically, they can diversify fossil fuel use for heating and cooking in certain rural areas, requiring a relatively low investment. Biomass-based briquettes or pellets could generate an energy output of 2 939 ktoe. This output could supply a large share of the Turkish heating and cooling targets of 3 537 ktoe.

Given the considerable potential found, the actual access of the biomass resources, the mobilisation of the resources and the technical deployment of this potential must be determined.

RECOMMENDATIONS

In the short-term, it is recommended that bioenergy production should focus on those residues that are either already collected in field or at the agro-processing plant. Residues that are already collected have low mobilisation costs as well as high accessibility. The assessment has identified a number of options that might be available for this. It is recommended to identify the most promising feedstock, both in terms of the quantity available as well as their technical suitability to be used for CHP, biogas production and for the production of briquettes and pellets. Based on the feedstock sections, the country can identify the province with highest availability and accessibility of that particular feedstock. Thereafter, the country can organize and conduct an exercise to verify and validate the actual feedstock availability and accessibility in the province identified.

In the medium to long term, efforts should be made to develop appropriate policies and mechanisms, as outlined above, to put in place an agricultural residue value chain that ensures a uniform and dependable supply of residues. This should involve cooperatives, intermediaries and a mechanism to encourage information exchange between energy producers and biomass owners as well as policies to introduce mechanisation equipment for the collection and pre-treatment of residues and storage facilities.

FIGURE 67.

Residue value chain from biomass producer to developer

There are challenges in collecting and mobilising residues for bioenergy generation (Figure 67). A key enabling factor could be to establish a biomass market and biomass supply chain that would allow for an easy exchange of residues between the biomass producer and bioenergy developer. Given the differences in infrastructural development status between east and west Turkey there may be issues with investment capacity as well as in logistics related activities and infrastructure that are crucial to collect and mobilise agricultural and livestock residues for bioenergy production.

Additionally, in order to have accurate information on residue availability, mechanisms that map and monitor residue uses at the regional level could be helpful. To build such mechanisms, establishing an inter-ministerial task force between the agriculture and energy ministries could be effective.

Some key questions that such a task force could examine are:

- How can provincial platforms for collection/pre-treatment be created?
- How to increase the mapping of possible users of residues?
- How to create standards of origin and quality specification of residues?

- Creation of a dedicated financial scheme aimed at biomass producers as well as bioenergy developers.

The government can actively encourage the development of the bioenergy sector through various means. Soft measures may be taken by the government to increase awareness about the importance of crop and livestock residues. Information dissemination programs aimed at farmers regarding various residue management practices and potential uses would be a useful starting point. Case studies and demonstration exercises which identify the major residues available in a particular province and their productive uses can be organized to increase awareness about the economic as well as environmental potential of appropriate residue management practices and end uses.

On the commercial side, hard measures are required to usher an entrepreneurial approach to residue use, especially for energy production. Availability of financial resources such as soft loans could be one instrument to encourage agro-industries where residue availability and accessibility is high, to build and operate on-site bioenergy plants.

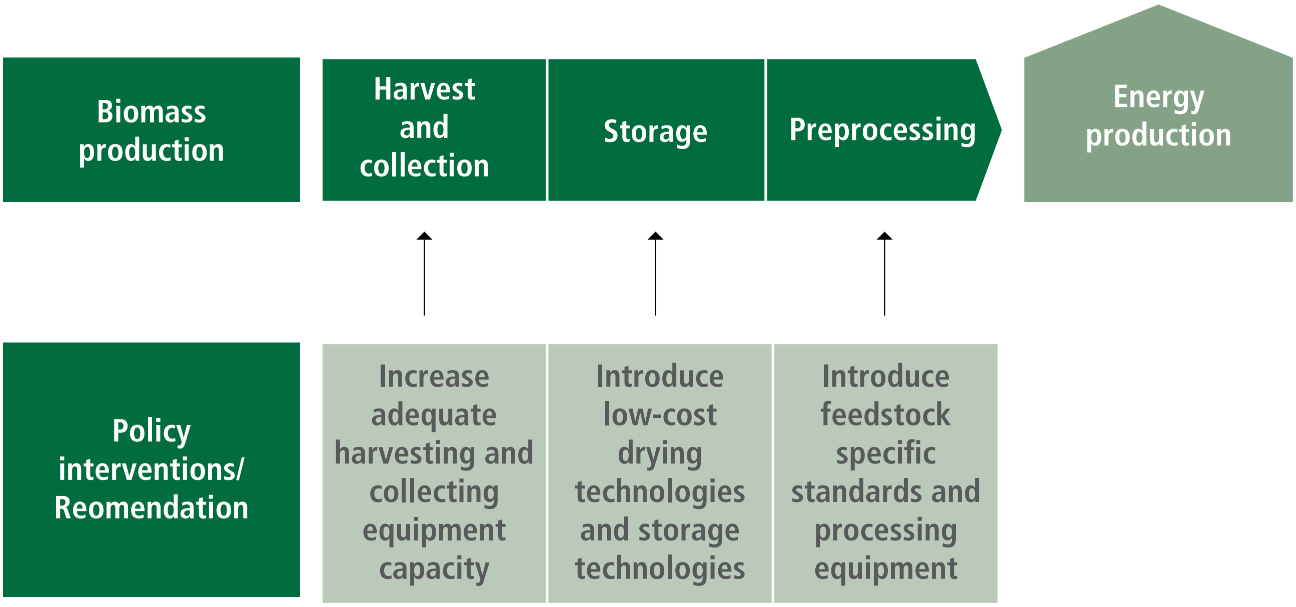
Other policy interventions addressing both the environmental problems caused by residue burning as well as supporting the development of an agro-residue value chain are required. This can be done by targeting each step of the residue value chain from harvesting to transportation. The Turkish bioenergy industry is constrained by the lack of supply system infrastructure. It is critical to demonstrate to the private sector that a uniform supply of feedstock of consistent properties can be done. For those residues that are left in the field, the residues logistics lies at the interface between production in the field, and its conversion into energy. The value chain involves the planning, implementation and control of the efficient and effective flow and storage of feedstock between supply and final use.

The key support areas are identified hereafter (Figure 68).

Harvest and collection - Harvesting and collection equipment and methods have a profound impact on the amount of residues that can be made available for various purposes. Depending on the type of harvesting and collection machinery, material losses can be minimised. However, these machineries are also costly and require substantial investment from farmers. The government needs to develop a program to introduce or pilot harvesting machinery that can reduce material losses but can also separate product and residues. It is estimated that in a bale-based feedstock supply chain, 14 operations employing 21 different types of machines are performed which increases losses. Better harvesting and collection machinery can also be made available to farmers by introducing machine sharing programs at a province level where farmers can rent and share this machinery during harvesting. However, a detailed region-specific policy on machine sharing would need to be put in place.

FIGURE 68.

Residue value chain as an interface between production and conversion to energy and possible policy interventions in the feedstock value chain



Storage – Storage of residues in an adequate environment is essential for bioenergy production. Many agricultural residues like maize stover are quite moist at the time of harvest and should be dried in order to be used for energy production. Depending on the feedstock storage scheme, the quality of feedstock can vary sharply. Where field drying is not possible, energy efficient mechanized drying can be used. Here again, mechanized drying equipment would need to be made available at a regional level to ensure a stable and uniform supply of residues.

Pre-processing – Before being used in a bioenergy plant, crop residues need to be processed to have the desired quality and particle size, as well as improve mobilisation. This can also have economic benefits to the supplier since higher and uniform quality feedstock would be compensated while low quality feedstock could be penalised. Indeed, feedstock quality can be affected at any stage of the supply chain but storage and pre-processing can have the highest impact on the quality of the residues. Moreover, densification methods such as pelletizing, and briquetting might help biomass mobilisation, reducing the volume occupied by biomass, increasing the total weight transported per load with the resulting the overall transport costs. There is a need to disseminate information on the importance of pre-processing of residue as well as methods and the importance for mobilisation and having a uniform particle size for bioenergy production. Active campaigns by the government to demonstrate pre-processing technologies as well as to make them available at province level would be required. In addition to this, defining the optimal properties of locally available feedstock and increasing the understanding of biomass properties that influence conversion to bioenergy would help in streamlining the feedstock characteristics at provincial level.

Energy production/processing - Capacity building and technology transfer promotion of more advanced and efficient bioenergy technologies particularly in rural areas might increase the awareness on the possibilities of bioenergy in the country as a complementary option to other renewable energies towards a reduction of fossil fuel dependence.

Special consideration regarding initial investment differences among bioenergy technologies should be made. Avoiding unrealistic situations or bioenergy projects where low-income communities would be theoretically able to buy high investment equipment replace their current practices by the operation of unknown technologies. Every particular case should be carefully considered analysing the each specific context. Thus, low-income communities would be benefited by small-scale biogas programs or briquette production project. While large-scale industries would have the know-how and the investment capacity to face large-scale bioenergy production using CHP or industrial biogas technologies.

Areas for further consideration

Technical meetings and expert workshops were held in Turkey with the lead government counterparts, country experts in the related fields and key institutions.

The discussions held during the meetings pointed to the following areas requiring further attention:

Knowledge of biomass options

The national stakeholders reported that the understanding of biomass and the potential for bioenergy is still limited and that there is currently no real market for biomass (some provinces are reported to be using sawdust). Results of what is really viable should be shared with the farmers in some form to start a discussion of what can realistically be accessed.

Stability of supply

Supply of feedstock needs to be quantifiable and stable in order to ensure viability for bioenergy operators. Due to this, farmers and processing plant operators should work in close coordination to ensure long terms viability of energy production. A farmer registration system to ensure stable biomass supply was proposed.

Residues versus waste

Concern was raised that agriculture crop residues or livestock residues could be considered waste versus feedstock that can be used for energy. It would advisable to use all residues so a new regulation system that can allow this and differentiate between waste and residues for energy use might be required. Current differentiation between by products and waste does not seem to be currently clear. The three ministries responsible for agriculture, energy and the environment should work together to clarify what is meant by these terms and the categorization of all residues. The final aim should be to have feedstock collection points that allow farmers to use the residues.

Real Accessibility

In practice, the figures in the field can change significantly. Accessibility can be a real problem and impede real long term sustainability of supply. Field-level validation of real accessibility is required.

Institutional level

There is a general perception that there might need to be more coordination across ministries and sectors related to bioenergy. It seems there might be misalignment between legislation and regulations resulting in issues with policy coherence and policy authority, coherence across ministries and objectives. The relevant institutions should raise awareness on how to use waste to ensure a clearer understanding of the issues, collaboration and coordination. In terms of biofuels, during a recent institutional meeting, there has been discussion on whether to form a biofuels supreme board to ensure coordination across ministries and policies. Ministries have to be coordinated to ensure that incentives, licensing, etc. are aligned. One additional first step could be to update the atlas of YEGM with the results of the analysis presented in the meeting.

Next steps

The nature of this assessment has involved a number of assumptions on the competing uses of agricultural and livestock residues, technical parameters and technology options. Although these assumptions are reasonable, it would be necessary to further verify and validate the results presented in the report. This is essential since the quantity and quality of bioenergy that can be produced in Turkey would depend on the quantity and stability of feedstock supply. The existing competing uses of crop and livestock residues can vary substantially across provinces affecting availability as well as accessibility. It is therefore recommended that a two-pronged approach be taken: short-term and long-term.

As an initial step, it would be advisable to conduct a local verification in the selected provinces of optimal choice and the use of these residues, energy needs, competing uses, and local costs, in order to understand the reasons why this potential is not currently being used in the country.

Additionally, the preliminary results of the agro-processing questionnaire, along with the field visit to the Central Black Sea Region, indicate that certain residues from sugar production, dairy processing, tea processing and other food processing (jams, juices, etc.) may be available for bioenergy production. Moreover, some of the agro-processing companies expressed their willingness to participate in future studies. It is therefore also worthwhile to explore partnership opportunities with these companies in these sectors to develop potential bioenergy solutions.

The results of this assessment might be used by the country to create an integrated and efficient strategy for the smart use of biomass residues available for bioenergy production at the national level, identifying specific bioenergy options that might be potentially profitable based on the biomass potential available within each specific region.

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ANNEX

1. CROP PRODUCTION INFORMATION

This section provides an overview of past and expected production trends for the identified crops (Table 48). The overview is based on the statistical data, published by TUIK and FAOSTAT, various market reports and includes explanations and comments provided by national experts during the technical consultation.

TABLE 48.

Details of harvest area, production quantity in the last available year and 5-year average

CROP NAME	YIELD (2014)	HARVEST AREA (AVERAGE, 2010 - 2014)	PRODUCTION (AVERAGE, 2010 - 2014)	YIELD (AVERAGE, 2010 - 2014)
Chestnut	0.032	11 797	59 808	0.03
Apricots	0.019	112 344	585 974	0.04
Walnut	0.026	55 397	191 519	0.03
Almonds	0.013	22 741	72 597	0.02
Olive	0.014	585 430	1 239 200	0.01
Pistachio	0.002	260 462	111 723	0.002
Hazelnut	0.001	693 906	530 200	0.001
Sugar beet	57 652	296 210	16 409 984	55.40
Rice	7.639	108 102	877 756	8.12
Maize	9.075	623 423	4 992 753	8.01
Cotton	5.034	485 755	2 330 013	4.80
Soybean	4.370	32 542	130 501	4.01
Groundnut	3.710	31 631	111 883	3.54
Triticale	3.153	32 532	108 424	3.33
Rye	2.650	132 703	353 671	2.67
Wheat	2.397	6 564 181	16 929 800	2.58
Barley	2.280	2 609 862	6 657 800	2.55
Oats	2.243	89 845	215 737	2.40
Sunflower	2.507	633 478	1 438 120	2.27
Chickpea	1.160	412 574	498 555	1.21
Tobacco	0.660	101 589	68 138	0.67

Note: The yields of crop in blue are tonnes/tree while the yields of all other crops is expressed in tonnes/ha.

1.1. Cereals

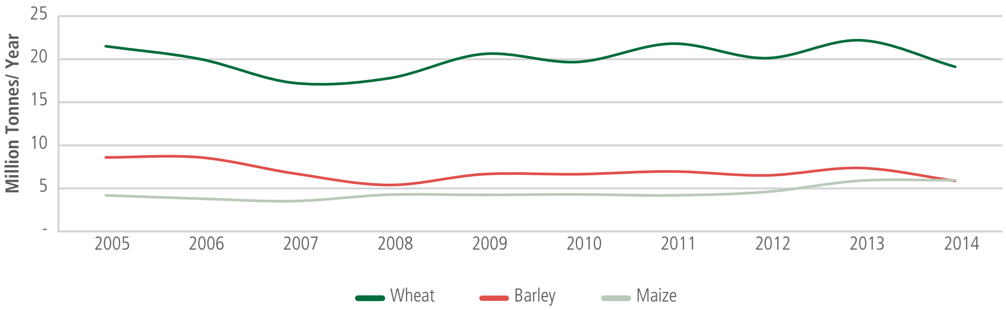
Wheat is a staple crop and the principal cereal in Turkey. It accounts for 62.08 percent of all cereals produced. The production was stable at around 20 million tonnes from 2004 to 2006, but dropped to 17.2 and 17.8 million in 2007 and 2008 respectively, primarily due to drought. The production picked up until 2014, when it fell again by 29 percent compared to 2013 (Figure 69). Turkey experienced a major drought followed by a cold autumn in 2013 and continued low precipitation during the spring months of 2014 (Kurnaz, 2014). The overall trend indicates a tendency for stable annual production of about 20 million tonnes. Among the provinces, Konya and Ankara (Central Anatolia Region) are the largest producers due to large land areas under wheat cultivation. During the observed period the highest yields were attained in Tekirdağ and Istanbul in the Marmara Region and Hatay in the Mediterranean Region.

Turkey is also one of the top ten producers of barley in the world. It contributes 22 percent to the overall cereals' produced in the country. Although relatively less volatile than wheat in terms of production, barley production did drop from about 8.5 million to 5.5 million tonnes between 2006 and 2008 but was then stable at around 6.6 million tonnes until 2012. High barley prices were the incentive for farmers to increase the area under production, switching from wheat, which resulted with a peak of 7.3 million tonnes in 2013 (USDA Foreign Agricultural Service, 2013). However, a sharp drop to 5.8 million tonnes followed in 2014, due to the drought. Konya, Ankara and Şanlıurfa are the provinces with the largest cultivation area and thus contribute the most to country level production. Marmara, though, is the highest-yielding agro-ecological zone.

Maize is the third most important cereal in Turkey, with a stable annual production of 3.8 to 4.3 million tonnes between 2005 and 2006. In 2013 and 2014 production jumped to about 5.9 million tonnes. The drivers for this increase lie in lower returns on cotton, increasing demand for feed and new fields with access to irrigation. Among the provinces, Adana, Sakarya and Şanlıurfa produce the most, because they have the biggest harvest area. Sivas, Bilecik and Isparta are the highest-yielding provinces.

FIGURE 69.

Annual production of the major cereals in Turkey



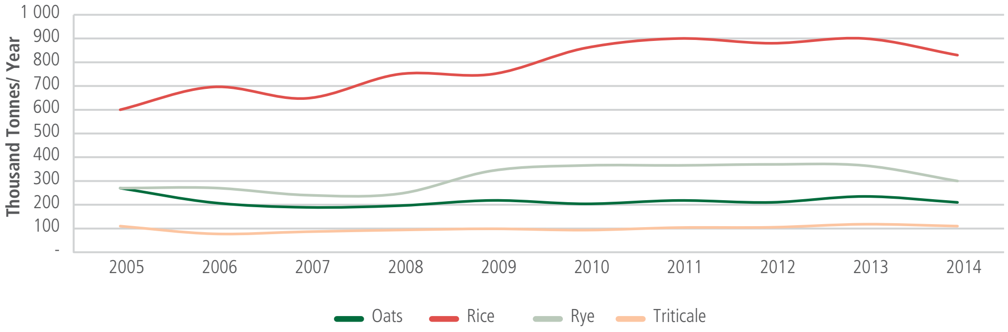
Source: TUIK, 2015

Other cereals produced in Turkey include rice, oats, rye and triticale. Among these, Rice is produced in the largest quantity and shows a trend of continuous increases in production over the last decade (

Figure 70). After reaching a peak of 900 000 tonnes in 2011, rice production stabilized around this level in the subsequent years. About 40 percent of rice is produced in Edirne, but the yield in Izmir is the highest in Turkey. Annual production of oats and triticale are mostly stable at 200 000 and 100 000 tonnes respectively, while that of rye held at around 250 000 tonnes in the first half of the observed period and then moved to about 350 000 after 2009. As in the case of wheat and barley, drought also affected the production of rice, oats, rye and triticale in 2014.

FIGURE 70.

Annual production of cereals in Turkey



Source: TUIK, 2015

1.2. Oilseeds, olive and chickpea

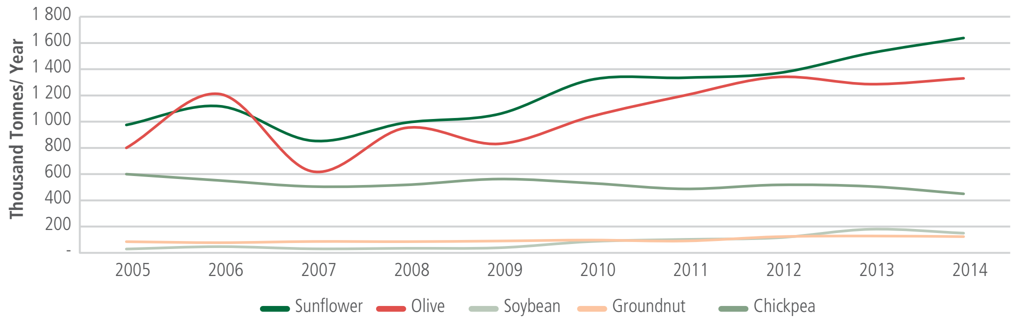
Sunflower is the most produced oilseed crop in Turkey. The production trend shows continuous growth since the early 2000s. This trend was interrupted by a drop in 2007 (from 1.1 million tonnes in 2006 to 0.8 million tonnes), but resumed with a strong jump in 2010 (from one million in 2009 to 1.3 million), after which the growth has been continuous, peaking at about 1.6 million tonnes in 2015 (Figure 71). Among the provinces Tekirdağ and Edirne in Marmara agro-ecological zone have the largest sunflower production, while Muğla is the highest-yielding province. There are two important incentives for farmers to engage in sunflower production and/or increase their production areas: governmental support which is received in the form of subsidies and the fact that sunflower is drought resistant, thus representing a crop with lower risk in respect to climatic extremes, which occur more often than in the preceding decades. Considering that sunflower oil is one of three most important food commodities in Turkey and that the country has been a net importer over the observed period, (at rates of 10 – 49 percent), it is reasonable to expect a continuation of government support and therefore possible further increases in the production. Production of olives shows similar trends to sunflower: there has been a strong upward trend since 2007, which was interrupted by a fall in 2009. Domestic supply increased from 72 to 93 percent of the production, imports remained negligible (less than 0.05 percent of the domestic supply).

The third most important oilseed crop is soybean. Its production increased slowly from 28 000 to 150 000 tonnes per year from 2005 to 2014. On average, Adana province, which has the largest production area, produced more than triple the amount produced in the second most important province, Mersin. In spite of the fact that domestic production in 2014 was more than five times higher compared to 2005, imports amounted to 93 percent of domestic supply.

Groundnut is also used to produce oil and for direct consumption. Its production has gradually increased since 2005, when it amounted to 86 000 tonnes, and reached 124 000 tonnes in 2014. Adana is the largest producer, while Isparta and Sirnak are the highest yield provinces. Ground nut oil production, however, has been constant at 10 000 tonnes per year, in spite of the increased groundnut production and higher demand. This may imply that the existing oil processing capacities are not sufficient to respond to domestic demand.

FIGURE 71.

Annual production of oilseeds, chickpea and olives in Turkey



Source: TUIK, 2015

Chickpea is one of the most important pulses in Turkish cuisine. Chickpea residues may be used as a feedstock for production of solid biofuels, however the practice not still not widespread. Over the last 10 years the production of chickpea has been stable, between 400 000 and 600 000 tonnes per year. Konya and Antalya are the country's top chickpea producers, while the highest yields were attained in Gümüşhane province.

1.3. Nuts and apricots

Turkey is the second most important nut exporter in the world. In 2009 it held 11.1 percent of the global nut market, which includes hazelnut, pistachios, walnuts, cashews, peanuts, almonds, etc.

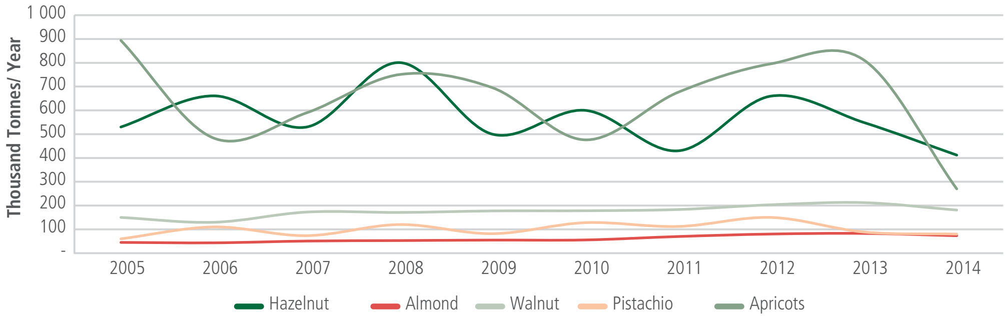
Hazelnut is the principal nut in Turkey with an average annual production of around 567 000 tonnes. The production volume follows a cyclical pattern with production peaking every second year. Over the last 10 year has remained above 500 000 tonnes, except in 2011 and 2014 when it dropped to 430 000 and 412 000 tonnes, respectively, due to adverse weather conditions. Production is mainly located along the Black Sea coast, with the plantation area being around 712 000 ha. The yields vary from 700 to 800 kg/ha, depending on the slope and therefore density as well as the age of plantations. Ordu, Sakarya and Giresun have more trees than other provinces and were the major contributors to the country level production. However, the 10-year average yield in Osmanlye province was 57.33 kg per bearing tree, almost four times higher than the average. As the farms in the eastern part of the Black Sea region are highly inclined compared to those in the western part, production efficiency is lower. In addition, the plantations in this region are older. On the contrary, the western parts of the region's plantations are young and located on fertile low inclined land, and thus the yields are higher.

Walnut production is much smaller than that of hazelnut but shows a positive production trend. Production increased from 150 000, in 2005, to 181 000 tonnes 2014. The national experts foresee further increases in production, which could be evident in the nest 15 to 30 years. Hakkari was the largest producer of walnut over the last 10 years, while the highest yields were attained in Ardahan province.

Pistachio production has kept steady around 100 000 tonnes per year in the last 10 years, and peaked reaching 150 000 and dropped falling to 60 000 and 73 000 tonnes. Gaziantep is the largest production province and Gümüşhane is the highest-yielding province. Finally, almond is the least produced nut. Its production was stable with gradual growth from 45 000 to around 83 000 tonnes during the past decade. Production is concentrated in the south eastern Mediterranean and Aegean regions.

FIGURE 72.

Annual production of fruit and nuts in Turkey



Source: TUIK, 2015

Turkey is the biggest apricot producer in the world and Malatya is the most important province, contributing to more than 50 percent to national production. The overall trend of apricot production in Turkey is a function of fluctuations in production in Malatya. The large reductions in production in 2006, 2010 and 2014 were caused mainly by adverse weather conditions in Malatya. When considering yields, Kars is the highest-yielding province

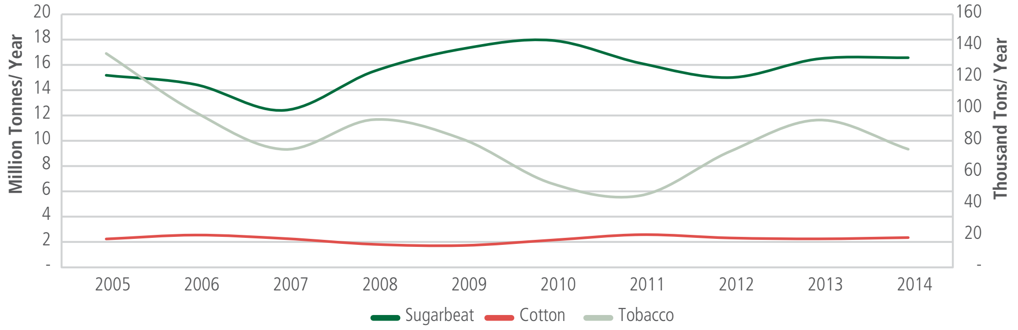
1.4. Sugar beet and cash crops

Under the Sugar Law (2001), sugar production in Turkey is regulated by the Turkish Sugar Board, which defines production quotas on an annual basis, for both sugar beet and starch based sugar (USDA Foreign Agricultural Service, 2015a). There are 33 production facilities managed by seven companies, of which 6 have been privatized since 2001 as stipulated by the Sugar Law (2001) Sugar beet is the principal sugar feedstock, the production of which reflects the annual sugar quotas.

In the period 2005 to 2014, average annual production of sugar beet was kept at around 15.6 million tonnes. However, for the last five years of the observed recorded average this levelled at 16.4 million tonnes with a peak of 17.9 million tonnes in 2010. Konya is the highest production province, with an amount produced more than three times that in Yozgat, which is the second-biggest sugar beet producer in Turkey. Bursa, Konya and Aksaray are the highest-yielding provinces.

FIGURE 73.

Production of sugar beet, cotton and tobacco in Turkey



Source: TUIK, 2015

Cotton is the most important industrial crop in Turkey, which ranks eight in the world cotton production. Most of the production is supplied to the domestic textile industry, thus fulfilling on average 50 percent of its cotton demand. However, cotton production is not regulated and depends on global market prices, as well as domestic prices of maize and cereals. Cotton is commonly planted on the same land as maize, thus the production (rotation) fluctuates according to government policies (subsidies) and the market conditions of these two crops. Despite annual fluctuations and regional changes, the national production level has been stable over the last 10 years, ranging between 1.73 and 2.35 million tonnes. Sanliurfa is the largest production province, and its production was around 3.57 times the one in Adana, which is the second-biggest producer in Turkey. Mersin, Adana and Hatay are the highest-yielding provinces. Based on different sources, it seems hard to foresee future trends in cotton production but it can be concluded that it will reflect global market trends and national agricultural policies, as it has over the last decade.

Turkey is also one of the largest tobacco producing countries in the world. The production, though, shows a declining trend, which may be a result of global market demands. The production declined from 135 000 in 2005 to 70 000 tonnes in 2014. The lowest production, at 45 000 tonnes, was observed in 2011. Manisa province ranks first in the production of tobacco.

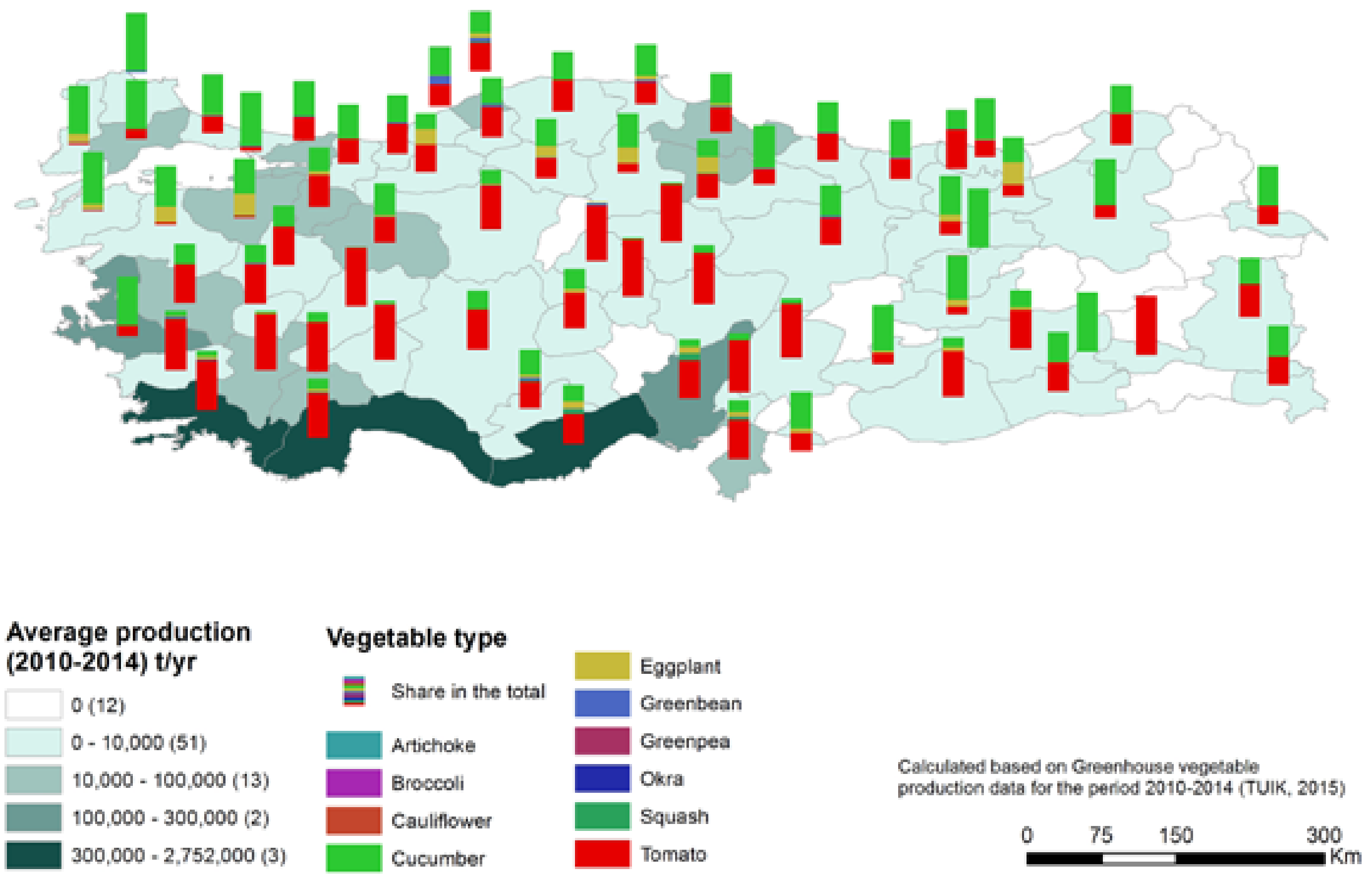
1.5. Crops produced in greenhouses

This section provides an overview of past and expected trends in the production quantities of 10 vegetables (produced in greenhouses), and it is based on the statistical data, published by TUIK and includes explanations and comments provided by national experts during the technical consultation.

There are 35 vegetable species grown in greenhouses in Turkey. Glass greenhouse, high tunnel, low tunnel and plastic greenhouse are the four types of greenhouse used in Turkey and the total amount of production and residues is presented in this report. Cucumber, tomatoes, parsley, eggplant and lettuce (loose leaf) are the five most popular vegetables, and their production accounts for 76.37 percent of the total greenhouse vegetable production. Moreover, cucumber and tomato, as the most widely planted vegetables, contribute 33.35 percent and 31.16 percent, respectively (TUIK, 2015).

FIGURE 74.

Greenhouse vegetable production in Turkey



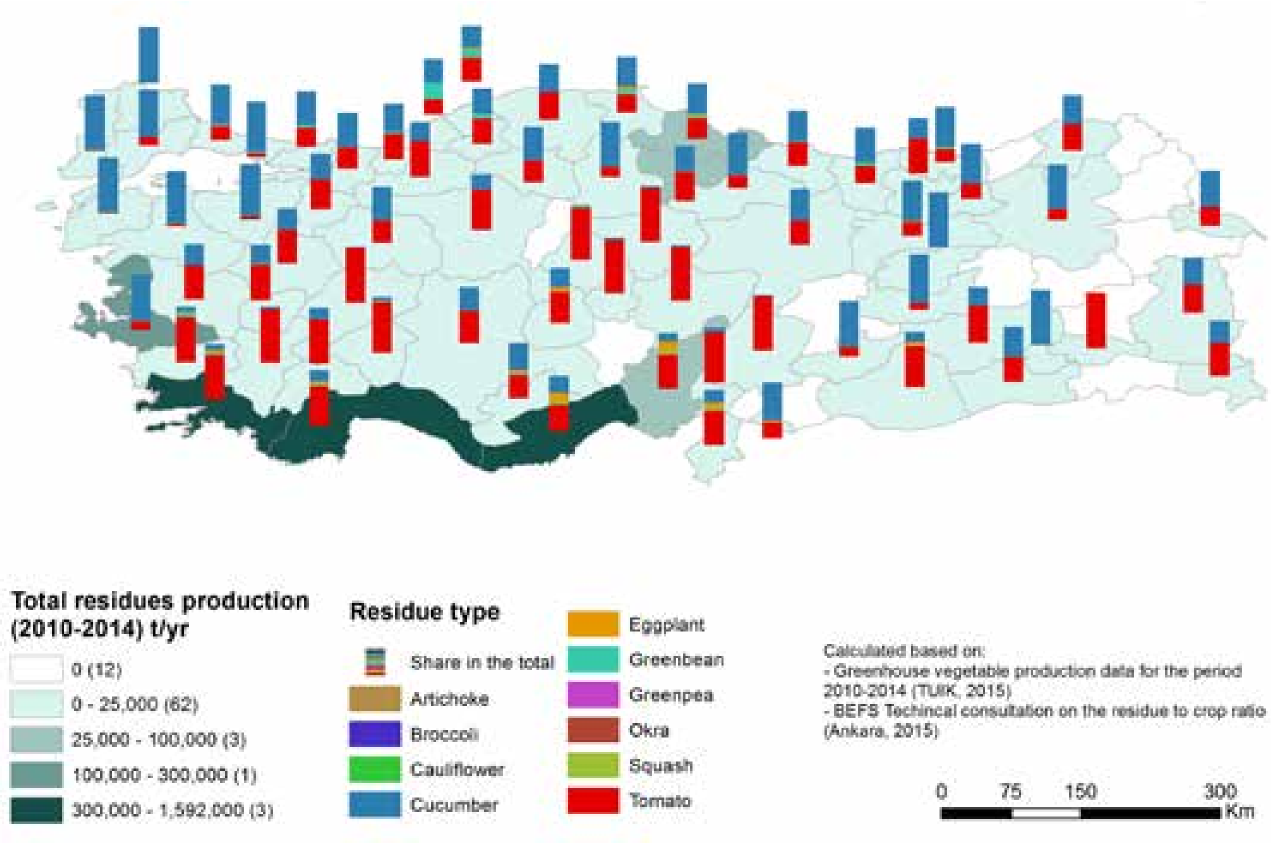
Calculated based on Greenhouse vegetable production data for the period 2010-2014 (TUIK, 2015)

The map shows the average annual production of vegetables in greenhouses based on total production for the period 2010-2014. Most greenhouse vegetables are produced in the Mediterranean and the western regions, with Antalya being the biggest producer of greenhouse vegetables. More specifically, most of the greenhouse tomato growers are in the southern part of the country, and most of the greenhouse cucumber growers are in the northern part of the country.

It should be noted that vegetable residues are a very good feed for livestock. Therefore, using vegetable for energy production should only be pursued in cases where they are not used as livestock feed.

FIGURE 75.

Greenhouse vegetable residues in Turkey



Calculated based on:
- Greenhouse vegetable production data for the period 2010-2014 (TUIK, 2015)
- BEFS Techincal consultation on the residue to crop ratio (Ankara, 2015)

The Mediterranean is the economic zone with the biggest greenhouse vegetables production, and also provides the largest residues. The amount of residues mainly comes from tomato, cucumber and eggplant. Apart from the Mediterranean zone, Izmir, Samsun and Amasya are the top three provinces where residues are generated. The largest amount of residues in both Izmir and Samsun are from cucumber, tomato and green peas. However, the types of residues for Amasya are tomato, cucumber, eggplant and squash. Overall, the residues in the southern provinces are mainly from tomato, and for the northern are from cucumber because of the planted areas.

TABLE 49.

Top greenhouse residues by province

REGION	TOP GREENHOUSE RESIDUES	TOP RANKING PROVINCE	RESIDUES (TONNES/YEAR)
Mediterranean	Tomatoes	Antalya	1 139 574.92
	Cucumber	Antalya	310 193.26
Aegean	Tomatoes	Mugla	243 331.55
	Cucumber	Izmir	90 495.73
Black Sea	Cucumber	Samsun	21 205.60
	Tomatoes	Samsun	14 236.53

2. LIVESTOCK PRODUCTION INFORMATION

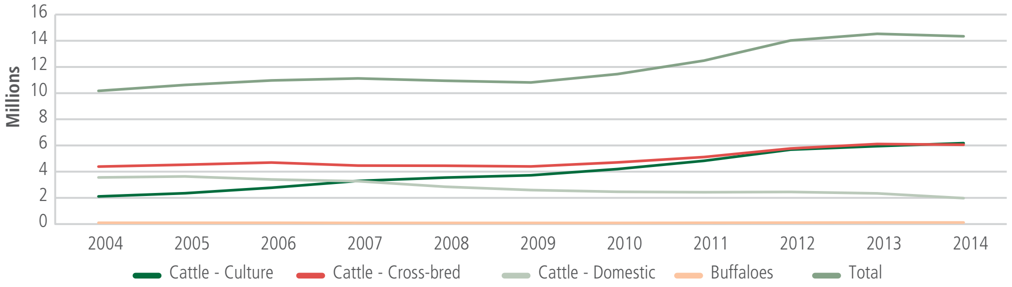
The livestock sector has traditionally been an important sector in Turkey. However, productivity remains low compared to other western European countries. The Turkish livestock sector is characterized by small-scale farms and domestic breeds, which are better able to adapt to the harsh climate of eastern Turkey but are less productive. In terms of farm sizes, the majority are small-scale with low-yielding local breeds that graze on pastures and meadows in the east while more mechanized farms exist in the west. Livestock products are an important source of household income for many farmers and households in rural areas. For small farmers, livestock products such as cattle, sheep and goat generate income and ensure food security for these households because an important amount of their incomes comes from the sales of animal and milk. Cattle population in Turkey have been volatile in the past with a decline in population during the late 2000s. The population trend has been positive since 2009 and continues to grow. The population trend of chicken has been also been fairly volatile with a steep decline during 2007 and 2008, flattened by 2009 and then picked up again thereafter. Regional variations also exist in that the more developed western regions have higher chicken population than the eastern regions. While Turkey also has substantial amount of sheep, this assessment focussed on cattle and chicken only.

2.1. Cattle

Cattle are reared in Turkey for meat, milk and hide. Cow is the most common type of cattle in Turkey, and production represented around 45 percent in the past 10 years. The number of bull and bullocks only accounted for 5 percent of total cattle. The number of culture cattle increased continuously from 2 million heads in 2004 to 6 million in 2013. The number of breed cattle showed a similar trend to culture cattle, rising from 4 million to 6 million heads during the last 10 years. However, the number of domestic cattle decreased from 4 million to 2 million. The number of buffalo kept steady at around 0.1 million heads over the last 10 years. The calves (less than 12 months) numbers accounted for 25 percent of total cattle, also young bull (12-24 months) and heifer (12-24 months) numbers represented 25 percent of total cattle. The number of female cattle was around 2.6 times that of male cattle. Although the number of all types of cattle increased 40 percent during the last 10 years, the proportion of female to male remains the same. Moreover, breed cattle, culture cattle, domestic cattle and buffalo had a similar composition of age and gender.

FIGURE 76.

Cattle and buffalo population trend

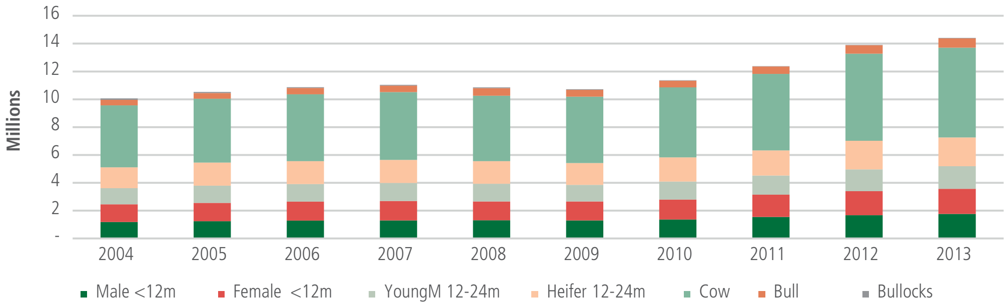


Source: Based on BEPA accessed in 2015

Cattle breed, age and gender are important variables to estimate the quantity of manure produced in a country. The different number of cattle by age and gender in Turkey is depicted in Figure 77. The Turkish government conducts agricultural surveys to monitor various agricultural production and management parameters including livestock population and holding size.

FIGURE 77.

Distribution of cattle by type, age and gender



Source: Based on BEPA accessed in 2015

BEPA (2015) provides province level information on the distribution of animal holdings by size. Holdings are distributed in 7 categories ranging from farms, which have between 1 to 5 animals to farms that have more than 200 animals (Table 50). Province level data was collected and collated from BEPA and a national average was calculated. Comparing the two tables, it is evident that there has been an increase the number of medium sized farms having 11 to 25 animals per farm, which housed 23 percent of total bovine animals. However, only 5 percent and 6 percent of bovine animals were held by the two holding size categories: 101-200 heads and 200+ heads.

TABLE 50.

Distribution of holdings of bovine animals by holding size

HOLDING SIZE ACCORDING TO NUMBER OF BOVINE ANIMALS (HEAD)	BOVINE ANIMALS (%)
1-5	17
6-10	18
11-25	23
26-50	16
51-100	15
101-200	5
>201	6

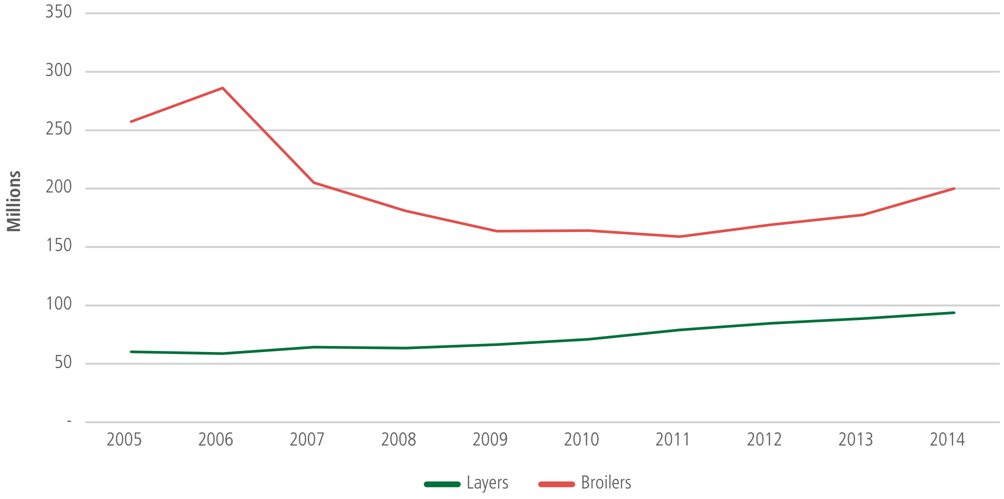
Source: BEPA accessed in 2015

2.2. Layers and broilers

The poultry sector is one of the strongest and most developed food industries in Turkey, and domestic poultry consumption and exports have been increasing over the past few years. Turkey obtained the permission to export processed poultry to the EU in August 2009 and has steadily been increasing its export to the EU since then. Layer population in Turkey, although much smaller than broiler population, has been increasing steadily for the past 10 years. The broiler population peaked between 2005 and 2007 after which it declined but picked up again in 2009-2010 (Figure 78).

FIGURE 78.

Layer and broiler population in Turkey

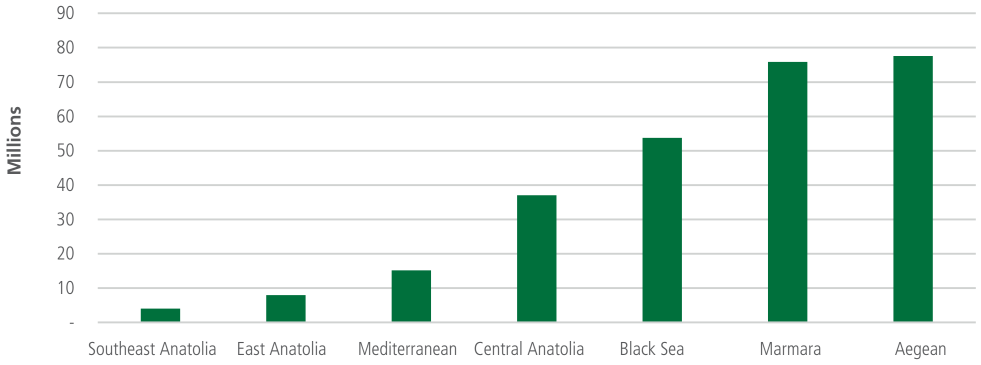


Source: Based on BEPA accessed in 2015

Poultry production in Turkey is concentrated in the eastern part of the country. The Aegean, Marmara and Black sea regions houses most of the poultry population (Figure 79). Poultry population in the eastern provinces of the country is smaller. In the western provinces however, the share of broiler chicken is considerably larger than that of layers while in the eastern provinces the share of layers is higher. For instance, in the Aegean region which houses the largest population of chicken, around 60 percent of all chicken are broilers, while in south east Anatolia, which has the lowest poultry population, around 78 percent of all chicken are layers. This is an important distinction since broiler manure is mixed with litter and hence is not very efficient feedstock for biogas production.

FIGURE 79.

Chicken production by region in Turkey

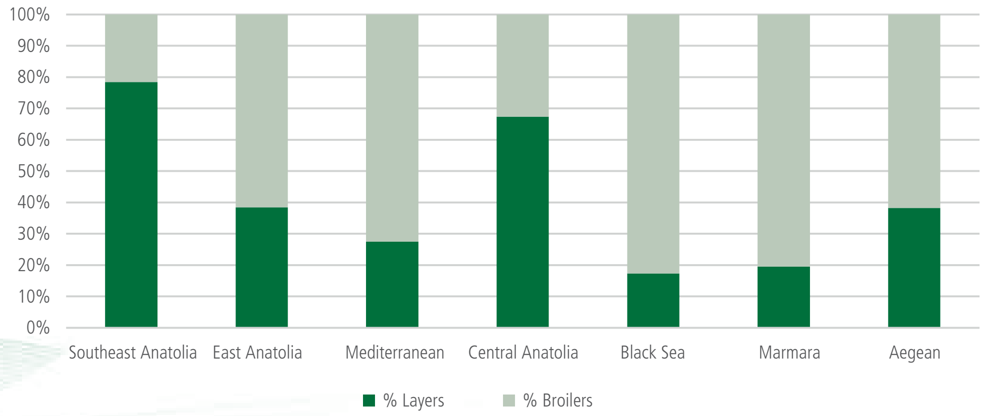


Source: Based on BEPA accessed in 2015

In terms of policy, the Turkish government has been implementing important changes in the livestock sector, with impacts for poultry production. For many years Turkey did not allow the imports of livestock and livestock products. Since 2010, however, Turkey has allowed selected imports of meat feeder and slaughter cattle as well exporting meat products to the EU after signing an agreement in 2009. Turkish poultry meat and egg exports had a strong start in 2015, but have fallen since May due to import bans by the main destinations due to avian influenza outbreaks in some regions of Turkey. The effect of rising modern poultry farms also has an effect on the feed production and price as well. Demand for compound feed has been growing in Turkey due to limited pasture areas and an increasing number of modern livestock and poultry operations. Broiler and egg production had increased at an average of seven percent annually during the last ten years in response to increasing domestic consumption and exports to neighbouring countries. Poultry producers are the most important end users of corn in Turkey. The poultry sector is one of the strongest and most developed food industries in Turkey, and domestic poultry consumption and exports have been increasing every year. Growth in 2014 was about two percent and total broiler meat production is estimated at 1.95 MMT (1.84 MMT for broiler meat). The industry also projects to grow at about two percent in 2015. The layer industry is the most rapidly growing section in the feed sector. In the last couple of years, layer feed production increased 2.5 times. The layer industry grew about seven percent in 2013, about six percent in 2014, and total production reached 17.6 billion eggs. Of Turkey's total exports, about 27 percent are exported to foreign markets, worth USD 404 million dollars. Turkey is ranked as one of the top ten largest egg producers in the world. The industry has grown about fifty percent between 2008 and 2012 as a result of both domestic consumption and increases in exports. Turkey continues to export about twenty-five percent of its egg production, mostly to neighbouring countries. The cost of feed contributed to around 65 percent of the final cost of egg. Domestic consumption of eggs is also increasing, reaching 185 eggs per person in 2014 (USDA Foreign Agricultural Service, 2015b).

FIGURE 80.

Distribution between layers and broilers across regions in Turkey



Source: Based on BEPA accessed in 2015

3. AVAILABILITY OF CROP RESIDUES AND PRODUCTION OF LIVESTOCK RESIDUES IN TURKEY

TABLE 51.

Availability of collected residues (Tonnes/Year)

PROVINCE	REGION	ALMOND SHELL	MAIZE COB	MAIZE HUSK	GROUNDNUT HUSK	PISTACHIO SHELL	RICE HUSK	HAZELNUT HUSK	SUNFLOWER HEAD
Adana	Mediterranean	274	148 043	41 123	5 355	1	130	-	112 130
Adiyaman	Souheast Anatolia	351	5 408	1 502	0	3 572	8	-	190
Afyon	Aegean	799	143	40	-	3	-	1	10 767
Agri	East Anatolia	-	-	-	-	-	-	-	743
Aksaray	Central Anatolia	46	1 688	469	-	-	-	-	52 288
Amasya	Black Sea	98	5 624	1 562	-	-	288	2	28 947
Ankara	Central Anatolia	721	706	196	-	7	201	-	38 994
Antalya	Mediterranean	2 277	9 089	2 525	326	7	-	15	328
Ãorum	Black Sea	141	210	58	-	24	14 994	-	40 279
Ardahan	East Anatolia	-	1	0	-	-	-	-	-
Artvin	Black Sea	-	907	252	-	-	54	3 412	-
Aydin	Aegean	696	29 680	8 244	546	184	-	-	2 185
Balikesir	Marmora	1 139	4 163	1 156	2	52	26 903	39	35 051
Bartin	Black Sea	-	2 901	806	-	-	-	1 652	628
Batman	Souheast Anatolia	168	4 729	1 314	-	290	-	-	-
Bayburt	Black Sea	-	0	0	-	-	-	-	-
Bilecik	Marmora	127	16	5	-	2	-	14	6 255
Bingöl	East Anatolia	12	114	32	-	-	64	-	147
Bitlis	East Anatolia	12	51	14	-	23	-	113	1 401
Bolu	Black Sea	46	14	4	-	-	18	100	2 286
Burdur	Mediterranean	411	155	43	-	3	-	-	418
Bursa	Marmora	257	24 176	6 716	-	7	4 536	220	32 446
Çanakkale	Marmora	1 789	4 178	1 161	5	302	19 557	19	46 997
Cankiri	Central Anatolia	191	3	1	-	-	4 087	-	1 506
Denizli	Aegean	1 825	11 541	3 206	-	266	-	6	42 607
Diyarbakir	Souheast Anatolia	1 169	26 038	7 233	-	501	2 559	-	3 376

PROVINCE	REGION	ALMOND SHELL	MAIZE COB	MAIZE HUSK	GROUNDNUT HUSK	PISTACHIO SHELL	RICE HUSK	HAZELNUT HUSK	SUNFLOWER HEAD
Duzce	Black Sea	2	5 511	1 531	-	-	465	19 832	-
Edirne	Marmora	145	2 745	763	10	-	88 946	-	276 011
Elazig	East Anatolia	708	226	63	-	32	-	-	4
Erzincan	East Anatolia	27	-	-	-	0	-	-	3 357
Erzurum	East Anatolia	5	112	31	-	-	22	-	3 683
Eskisehir	Central Anatolia	355	1 588	441	-	12	-	-	36 987
Gaziantep	Souheast Anatolia	597	7 478	2 077	31	17 305	-	-	2 308
Giresun	Black Sea	-	1 312	364	-	-	-	22 448	-
Gümüşhane	Black Sea	-	63	18	-	-	-	260	-
Hakkari	East Anatolia	7	9	2	-	24	76	-	9
Hatay	Mediterranean	430	25 665	7 129	62	5	37	4	3 159
Igdir	East Anatolia	-	2 986	829	-	-	468	-	218
Isparta	Mediterranean	1 540	41	11	10	4	-	33	148
Istanbul	Marmora	45	81	22	-	-	569	325	41 307
Izmir	Aegean	566	29 978	8 327	0	482	201	-	4 362
Kahramanmaraş	Mediterranean	318	35 063	9 740	441	1 968	7	91	21 673
Karabuk	Black Sea	29	75	21	-	12	79	-	107
Karaman	Central Anatolia	886	16 321	4 534	3	112	-	-	14 570
Kars	East Anatolia	-	-	-	-	-	-	-	216
Kastamonu	Black Sea	6	360	100	-	-	1 224	1 480	-
Kayseri	Central Anatolia	35	396	110	-	-	-	-	14 051
Kilis	Souheast Anatolia	405	1 126	313	-	760	-	-	154
Kirikkale	Central Anatolia	115	594	165	-	-	1 384	-	14 470
Kirklareli	Marmora	53	6 321	1 756	-	-	5 112	13	159 721
Kirsehir	Central Anatolia	64	198	55	-	-	-	-	16 835
Kocaeli	Marmora	-	6 529	1 814	-	-	-	3 232	1 641
Konya	Central Anatolia	531	47 196	13 110	-	167	-	-	211 937
Kütahya	Aegean	225	527	146	-	125	-	2	3 739
Malatya	East Anatolia	185	65	18	-	101	-	-	762
Manisa	Aegean	1 104	52 046	14 457	1	579	-	-	1 085

PROVINCE	REGION	ALMOND SHELL	MAIZE COB	MAIZE HUSK	GROUNDNUT HUSK	PISTACHIO SHELL	RICE HUSK	HAZELNUT HUSK	SUNFLOWER HEAD
Mardin	Souheast Anatolia	657	81 745	22 707	-	521	128	-	-
Mersin	Mediterranean	3 470	33 172	9 214	190	522	576	-	4 891
Mugla	Aegean	3 016	3 175	882	44	71	-	-	799
Mus	East Anatolia	-	88	24	-	-	-	-	4 049
Nevsehir	Central Anatolia	577	6	2	-	1	-	-	525
Nigde	Central Anatolia	50	100	28	0	-	-	-	164
Ordu	Black Sea	-	2 686	746	-	-	-	41 611	-
Osmaniye	Mediterranean	45	61 088	16 969	3 777	-	45	-	10 049
Rize	Black Sea	-	132	37	-	-	-	529	-
Sakarya	Marmora	161	58 928	16 369	-	-	-	28 810	7 645
Samsun	Black Sea	-	17 499	4 861	-	-	30 002	22 958	35 125
Sanliurfa	Souheast Anatolia	591	99 039	27 511	-	14 893	2 193	-	4 384
Siirt	Souheast Anatolia	146	1 644	457	-	6 298	1	-	-
Sinop	Black Sea	22	2 868	797	-	-	7 401	368	-
Sirnak	Souheast Anatolia	51	2 799	778	103	14	-	-	170
Sivas	Central Anatolia	1	-	-	-	25	-	4	814
Tekirdag	Marmora	180	299	83	-	-	6 804	-	271 048
Tokat	Black Sea	160	3 339	928	-	-	301	604	34 504
Trabzon	Black Sea	-	3 280	911	-	-	-	13 678	-
Tunceli	East Anatolia	188	-	-	-	11	-	-	-
Usak	Aegean	538	231	64	-	34	-	-	1 170
Van	East Anatolia	1	-	-	-	0	-	-	223
Yalova	Marmora	0	6	2	-	-	-	8	67
Yozgat	Central Anatolia	67	17	5	-	-	-	-	7 243
Zinguldak	Black Sea	-	2 365	657	-	-	-	7 783	57

TABLE 52.

Availability of residues spread in the field (Tonnes/Year)

PROVINCE	REGION	MAIZE STALK	COTTON STALK	RICE STRAW	SUNFLOWE STALK	SOYBEAN HUSK	TABOCCO STALK	SOYBEAN STALK
Adana	Mediterranean	1 159 669	1 306 512	518	123 679	-	-	52 884
Adiyaman	Souheast Anatolia	42 360	295 365	31	210	1 077	3 987	4
Afyon	Aegean	1 117	-	-	11 876	-	38	1
Agri	East Anatolia	-	-	-	819	5	-	-
Aksaray	Central Anatolia	13 219	-	-	57 674	18	-	-
Amasya	Black Sea	44 053	-	1 153	31 928	-	720	77
Ankara	Central Anatolia	5 527	-	802	43 010	-	-	-
Antalya	Mediterranean	71 195	154 054	-	361	46	-	-
Ãorum	Black Sea	1 644	-	59 978	44 428	-	-	11
Ardahan	East Anatolia	9	-	-	-	0	-	-
Artvin	Black Sea	7 102	-	214	-	-	-	-
Aydin	Aegean	232 491	1 423 919	-	2 410	-	2 467	32
Balikesir	Marmora	32 613	9 331	107 610	38 661	-	3 106	-
Bartin	Black Sea	22 722	-	-	693	10	-	-
Batman	Souheast Anatolia	37 046	24 002	-	-	-	1 365	-
Bayburt	Black Sea	2	-	-	-	1	-	-
Bilecik	Marmora	127	-	-	6 900	-	-	-
Bingöl	East Anatolia	896	-	256	163	-	-	-
Bitlis	East Anatolia	401	-	-	1 545	0	655	-
Bolu	Black Sea	107	-	71	2 522	-	-	-
Burdur	Mediterranean	1 217	-	-	462	-	11	1
Bursa	Marmora	189 379	97	18 144	35 788	-	71	-
Çanakkale	Marmora	32 728	3 545	78 228	51 838	2 367	277	6
Cankiri	Central Anatolia	25	-	16 349	1 661	5	-	-
Denizli	Aegean	90 401	149 033	-	46 996	563	17 627	-
Diyarbakir	Souheast Anatolia	203 967	985 523	10 237	3 724	-	139	174
Duzce	Black Sea	43 169	-	1 859	-	-	696	-
Edirne	Marmora	21 503	-	355 785	304 442	-	-	-

PROVINCE	REGION	MAIZE STALK	COTTON STALK	RICE STRAW	SUNFLOWE STALK	SOYBEAN HUSK	TABOCCO STALK	SOYBEAN STALK
Elazig	East Anatolia	1 773	-	-	4	-	-	-
Erzincan	East Anatolia	-	-	-	3 702	1	-	-
Erzurum	East Anatolia	880	-	89	4 062	-	-	-
Eskisehir	Central Anatolia	12 442	-	-	40 797	-	-	-
Gaziantep	Souheast Anatolia	58 575	232 424	-	2 546	-	124	34
Giresun	Black Sea	10 275	-	-	-	-	4	-
Gümüşhane	Black Sea	494	-	-	-	-	-	-
Hakkari	East Anatolia	69	-	306	10	-	19	-
Hatay	Mediterranean	201 044	1 196 669	148	3 484	-	2 581	61
Igdir	East Anatolia	23 388	-	1 871	240	3	-	17
Isparta	Mediterranean	319	-	-	163	-	-	-
Istanbul	Marmora	631	-	2 278	45 561	-	-	-
Izmir	Aegean	234 829	672 184	805	4 812	-	2 983	-
Kahramanmaraş	Mediterranean	274 659	126 521	27	23 905	-	-	1 109
Karabuk	Black Sea	589	-	316	118	-	-	-
Karaman	Central Anatolia	127 847	-	-	16 070	-	-	-
Kars	East Anatolia	-	-	-	238	-	-	-
Kastamonu	Black Sea	2 821	-	4 897	-	-	-	-
Kayseri	Central Anatolia	3 102	-	-	15 498	-	-	-
Kilis	Souheast Anatolia	8 819	5 051	-	170	-	-	-
Kirikkale	Central Anatolia	4 655	-	5 537	15 960	-	-	-
Kirklareli	Marmora	49 516	-	20 450	176 173	-	66	-
Kirsehir	Central Anatolia	1 551	-	-	18 569	-	-	-
Kocaeli	Marmora	51 141	-	-	1 810	-	-	-
Konya	Central Anatolia	369 701	-	-	233 768	-	-	114
Kütahya	Aegean	4 128	-	-	4 125	-	72	-
Malatya	East Anatolia	506	-	-	841	-	1 129	-
Manisa	Aegean	407 695	107 089	-	1 196	-	21 531	-
Mardin	Souheast Anatolia	640 340	461 497	513	-	-	136	2 151
Mersin	Mediterranean	259 848	105 558	2 302	5 395	9	-	15 087

PROVINCE	REGION	MAIZE STALK	COTTON STALK	RICE STRAW	SUNFLOWE STALK	SOYBEAN HUSK	TABOCCO STALK	SOYBEAN STALK
Mugla	Aegean	24 874	17 989	-	882	-	1 590	-
Mus	East Anatolia	689	-	-	4 466	2	284	292
Nevsehir	Central Anatolia	43	-	-	579	-	-	-
Nigde	Central Anatolia	783	-	-	181	-	-	-
Ordu	Black Sea	21 042	-	-	-	-	-	-
Osmaniye	Mediterranean	478 519	11 817	180	11 084	99	9	3 589
Rize	Black Sea	1 035	-	-	-	-	-	-
Sakarya	Marmora	461 601	-	-	8 433	-	512	-
Samsun	Black Sea	137 079	-	120 007	38 743	-	6 204	6 865
Sanliurfa	Souheast Anatolia	775 809	5 123 235	8 772	4 836	-	-	57
Siirt	Souheast Anatolia	12 878	8 877	5	-	-	21	-
Sinop	Black Sea	22 466	-	29 603	-	-	6	-
Sirnak	Souheast Anatolia	21 928	126 699	-	188	337	-	628
Sivas	Central Anatolia	-	-	-	897	-	-	-
Tekirdag	Marmora	2 342	-	27 217	298 967	-	1	-
Tokat	Black Sea	26 156	-	1 202	38 058	-	2 391	-
Trabzon	Black Sea	25 692	-	-	-	174	2	-
Tunceli	East Anatolia	-	-	-	-	8 296	-	-
Usak	Aegean	1 810	131	-	1 291	-	5 833	-
Van	East Anatolia	-	-	-	245	12	-	-
Yalova	Marmora	48	-	-	74	-	-	-
Yozgat	Central Anatolia	135	-	-	7 989	27	-	-
Zinguldak	Black Sea	18 528	-	-	63	-	-	-

TABLE 53.

Production of cattle and buffalo manure (Tonnes/Year)

PROVINCE	REGION	CULTURE CATTLE	DOMESTIC CATTLE	BREED CATTLE	BUFFALO	TOTAL
Adana	Mediterranean	795 405	135 508	1 436 698	2 188	2 369 800
Adiyaman	Souheast Anatolia	359 108	139 866	274 157	-	773 130
Afyon	Aegean	2 714 714	237 441	509 003	53 262	3 514 419
Agri	East Anatolia	214 567	1 342 568	1 196 646	5 294	2 759 076
Aksaray	Central Anatolia	1 358 269	106 337	561 579	6 682	2 032 868
Amasya	Black Sea	557 448	424 124	635 503	39 618	1 656 693
Ankara	Central Anatolia	1 193 908	481 877	1 276 726	10 633	2 963 143
Antalya	Mediterranean	830 731	130 111	634 999	3 055	1 598 896
Ãorum	Black Sea	1 000 731	279 179	1 029 607	22 189	2 331 707
Ardahan	East Anatolia	181 134	334 790	2 399 576	156	2 915 657
Artvin	Black Sea	190 595	128 444	325 578	-	644 617
Aydin	Aegean	3 048 900	297 437	400 129	2 766	3 749 231
Balikesir	Marmora	5 202 660	173 796	957 968	26 088	6 360 512
Bartin	Black Sea	179 628	61 788	293 243	20 266	554 924
Batman	Souheast Anatolia	289 702	124 768	154 437	3 655	572 562
Bayburt	Black Sea	152 965	35 412	450 896	5 053	644 327
Bilecik	Marmora	315 876	9 776	129 766	71	455 489
Bingöl	East Anatolia	422 933	148 072	729 966	1 797	1 302 768
Bitlis	East Anatolia	294 538	183 055	312 656	60 291	850 540
Bolu	Black Sea	650 943	146 142	541 158	14 717	1 352 961
Burdur	Mediterranean	2 211 931	29 005	112 675	27	2 353 638
Bursa	Marmora	1 652 098	69 415	421 794	12 022	2 155 328
Çanakkale	Marmora	2 173 088	96 986	189 908	5 258	2 465 241
Cankiri	Central Anatolia	434 856	134 677	645 328	13 835	1 228 696
Denizli	Aegean	2 683 073	19 537	157 792	702	2 861 104
Diyarbakir	Souheast Anatolia	1 008 672	1 099 318	1 131 410	110 111	3 349 511
Duzce	Black Sea	186 619	188 737	218 048	34 226	627 630
Edirne	Marmora	1 565 003	32 437	350 420	1 676	1 949 536
Elazig	East Anatolia	521 622	183 884	757 749	382	1 463 637
Erzincan	East Anatolia	308 244	91 643	551 050	15 055	965 991
Erzurum	East Anatolia	904 311	603 400	4 595 097	12 414	6 115 221

PROVINCE	REGION	CULTURE CATTLE	DOMESTIC CATTLE	BREED CATTLE	BUFFALO	TOTAL
Eskisehir	Central Anatolia	878 495	120 254	346 861	3 550	1 349 160
Gaziantep	Souheast Anatolia	902 986	53 883	597 737	1 418	1 556 025
Giresun	Black Sea	198 377	219 243	413 949	28 408	859 976
Gümüşhane	Black Sea	296 456	203 179	237 653	1 380	738 667
Hakkari	East Anatolia	54 243	167 119	116 547	545	338 454
Hatay	Mediterranean	475 535	85 184	790 964	7 527	1 359 210
Igdir	East Anatolia	250 681	191 257	674 141	13 012	1 129 092
Isparta	Mediterranean	975 899	177 643	255 479	2 044	1 411 064
Istanbul	Marmora	192 871	32 388	444 065	112 690	782 015
Izmir	Aegean	4 611 781	162 574	1 009 052	660	5 784 067
Kahramanmaraş	Mediterranean	740 754	108 214	670 775	514	1 520 257
Karabuk	Black Sea	77 490	120 574	227 898	12 671	438 633
Karaman	Central Anatolia	413 587	10 115	187 123	670	611 494
Kars	East Anatolia	647 680	1 331 195	2 696 027	275	4 675 177
Kastamonu	Black Sea	1 166 118	466 410	992 777	11 387	2 636 693
Kayseri	Central Anatolia	1 445 323	166 739	1 339 505	45 766	2 997 333
Kilis	Souheast Anatolia	78 285	-	69 958	-	148 243
Kirikkale	Central Anatolia	205 016	104 905	361 057	1 423	672 401
Kirklareli	Marmora	1 621 166	26 743	139 567	16 621	1 804 098
Kirsehir	Central Anatolia	446 569	122 197	519 818	996	1 089 580
Kocaeli	Marmora	473 771	70 341	560 715	17 156	1 121 983
Konya	Central Anatolia	5 119 625	398 781	1 821 983	2 595	7 342 985
Kütahya	Aegean	1 003 355	165 789	669 563	21 893	1 860 601
Malatya	East Anatolia	500 173	98 779	719 957	-	1 318 910
Manisa	Aegean	1 075 230	183 718	1 121 904	6 319	2 387 171
Mardin	Souheast Anatolia	291 651	328 765	237 189	-	857 604
Mersin	Mediterranean	602 733	40 696	647 595	504	1 291 527
Mugla	Aegean	965 974	118 583	741 770	-	1 826 328
Mus	East Anatolia	586 113	839 917	1 204 186	67 688	2 697 904
Nevsehir	Central Anatolia	432 676	9 605	307 719	810	750 810
Nigde	Central Anatolia	1 235 442	10 285	253 232	173	1 499 132
Ordu	Black Sea	284 441	164 484	921 848	10 145	1 380 919
Osmaniye	Mediterranean	323 732	12 553	480 273	3 144	819 702

PROVINCE	REGION	CULTURE CATTLE	DOMESTIC CATTLE	BREED CATTLE	BUFFALO	TOTAL
Rize	Black Sea	40 735	37 285	148 765	47	226 832
Sakarya	Marmora	893 882	90 666	925 174	11 306	1 921 029
Samsun	Black Sea	922 426	642 093	1 580 883	159 946	3 305 348
Sanliurfa	Souheast Anatolia	592 496	567 061	784 706	3 676	1 947 940
Siirt	Souheast Anatolia	59 016	97 294	76 031	-	232 341
Sinop	Black Sea	173 816	289 863	473 754	11 157	948 591
Sirnak	Souheast Anatolia	51 634	182 803	77 324	1 689	313 449
Sivas	Central Anatolia	1 197 101	71 492	2 167 905	40 100	3 476 599
Tekirdag	Marmora	1 597 329	15 239	199 200	6 243	1 818 011
Tokat	Black Sea	831 094	523 493	1 076 602	83 285	2 514 474
Trabzon	Black Sea	272 837	119 823	841 196	2 917	1 236 774
Tunceli	East Anatolia	117 952	47 152	128 658	-	293 762
Usak	Aegean	1 253 251	9 836	129 943	-	1 393 029
Van	East Anatolia	353 447	662 685	660 208	9 215	1 685 555
Yalova	Marmora	74 494	11 729	38 963	28	125 215
Yozgat	Central Anatolia	1 165 228	525 325	899 897	22 463	2 612 913
Zinguldak	Black Sea	322 387	144 005	339 795	5 856	812 042

TABLE 54.

Production of chicken manure (Tonnes/Year)

PROVINCE	REGION	CULTURE CATTLE	DOMESTIC CATTLE	BREED CATTLE
Adana	Mediterranean	40 316	93 667	133 983
Adiyaman	Souheast Anatolia	12 019	1 809	13 828
Afyon	Aegean	673 174	7 452	680 627
Agri	East Anatolia	8 009	756	8 765
Aksaray	Central Anatolia	16 164	32	16 196
Amasya	Black Sea	68 236	2 817	71 053
Ankara	Central Anatolia	224 860	142 906	367 766
Antalya	Mediterranean	26 115	-	26 115
Ãorum	Black Sea	7 134	-	7 134
Ardahan	East Anatolia	628	-	628
Artvin	Black Sea	34 651	59 952	94 603
Aydin	Aegean	335 063	616 451	951 515
Balikesir	Marmora	9 932	19 899	29 831
Bartin	Black Sea	8 790	192	8 983
Batman	Souheast Anatolia	5 145	-	5 145
Bayburt	Black Sea	11 491	26 743	38 234
Bilecik	Marmora	4 731	-	4 731
Bingöl	East Anatolia	4 105	-	4 105
Bitlis	East Anatolia	31 195	753 905	785 101
Bolu	Black Sea	9 224	-	9 224
Burdur	Mediterranean	222 326	124 715	347 041
Bursa	Marmora	13 243	134 805	148 047
Çanakkale	Marmora	18 457	42 503	60 960
Cankiri	Central Anatolia	222 799	7 394	230 192
Denizli	Aegean	93 924	40 792	134 716
Diyarbakir	Souheast Anatolia	26 331	270	26 601
Duzce	Black Sea	19 848	232 411	252 259
Edirne	Marmora	12 065	1 466	13 531
Elazig	East Anatolia	33 215	70 591	103 805
Erzincan	East Anatolia	25 336	1 620	26 956
Erzurum	East Anatolia	10 150	-	10 150
Eskisehir	Central Anatolia	66 245	98 582	164 827
Gaziantep	Souheast Anatolia	72 080	15 775	87 855

PROVINCE	REGION	CULTURE CATTLE	DOMESTIC CATTLE	BREED CATTLE
Giresun	Black Sea	1 350	-	1 350
Gümüşhane	Black Sea	5 137	-	5 137
Hakkari	East Anatolia	2 405	-	2 405
Hatay	Mediterranean	23 232	16 307	39 539
Igdir	East Anatolia	5 561	-	5 561
Isparta	Mediterranean	14 293	-	14 293
Istanbul	Marmora	51 768	16 614	68 382
Izmir	Aegean	240 431	343 340	583 770
Kahramanmaraş	Mediterranean	16 199	1 921	18 119
Karabuk	Black Sea	13 497	14 261	27 758
Karaman	Central Anatolia	64 928	162	65 090
Kars	East Anatolia	11 745	-	11 745
Kastamonu	Black Sea	13 057	1 454	14 511
Kayseri	Central Anatolia	199 860	13 114	212 974
Kilis	Souheast Anatolia	4 726	4 159	8 885
Kirikkale	Central Anatolia	34 008	3 053	37 061
Kirklareli	Marmora	18 395	767	19 162
Kirsehir	Central Anatolia	24 325	-	24 325
Kocaeli	Marmora	31 820	187 121	218 941
Konya	Central Anatolia	589 708	17 359	607 067
Kütahya	Aegean	61 505	4 892	66 397
Malatya	East Anatolia	20 393	59 193	79 586
Manisa	Aegean	482 722	629 809	1 112 531
Mardin	Souheast Anatolia	21 133	15	21 148
Mersin	Mediterranean	87 476	179 433	266 909
Mugla	Aegean	29 464	5 153	34 616
Mus	East Anatolia	14 351	-	14 351
Nevsehir	Central Anatolia	40 968	1 486	42 454
Nigde	Central Anatolia	23 489	5 670	29 159
Ordu	Black Sea	12 608	2 145	14 753
Osmaniye	Mediterranean	10 767	5 348	16 115
Rize	Black Sea	647	41	688
Sakarya	Marmora	69 606	540 519	610 125
Samsun	Black Sea	73 996	42 589	116 585
Sanliurfa	Souheast Anatolia	19 908	1 271	21 179

PROVINCE	REGION	CULTURE CATTLE	DOMESTIC CATTLE	BREED CATTLE
Siirt	Souheast Anatolia	4 478	-	4 478
Sinop	Black Sea	6 275	-	6 275
Sirnak	Souheast Anatolia	3 386	14	3 400
Sivas	Central Anatolia	25 619	-	25 619
Tekirdag	Marmora	38 657	27	38 684
Tokat	Black Sea	12 291	-	12 291
Trabzon	Black Sea	2 227	-	2 227
Tunceli	East Anatolia	1 556	-	1 556
Usak	Aegean	8 604	201 141	209 744
Van	East Anatolia	18 348	-	18 348
Yalova	Marmora	5 167	338	5 504
Yozgat	Central Anatolia	36 298	1 592	37 890
Zinguldak	Black Sea	10 093	122 836	132 929

4. TECHNO-ECONOMIC INFORMATION

TABLE 55.

Local raw materials, energy and supplies costs & salaries & prices

	RATE	
Skilled Worker (Agriculture)	2.14	USD/h
Unskilled Worker (Agriculture)	3.04	USD/h
Skilled Worker (Industrial)	10.27	USD/h
Unskilled Worker (Industrial)	2.14	USD/h
Water (Rural Households)	1.55	USD/m^3
Water (Agriculture)	2.21	USD/m^3
Water (Industry)	3.53	USD/m^3
Electricity (Industry)	0.10	USD/kWh
Electricity (Feed-in)	0.13	USD/kWh
Heat Price (Households)*	12	USD/GJ
Heat Price (Selling)**	6	USD/GJ
Transport Cost – Biomass	0.14	USD/t/km
Transport Cost – Briquettes/Pellet	0.16	USD/t/km
Diesel Price***	1.55	USD/l
Caustic Soda	390	USD/t
Maize Flour	1 215	USD/t
Wheat Flour	506	USD/t

*Heating costs total of a building with 24 houses in Ankara. Total 1 month consumption is 34 490 kWh, costs 3 915 TL (1 kWh = 3.6 MJ). Therefore, the current heat cost is 12 USD/GJ.

**The cost of distributing the heat from the plant to the end user must be taken into account and included in the calculation. Therefore, a conservative assumption would be to assign a 50 percent heat cost to go towards this distribution (Poyry Energy Consulting, 2009).

***Averaged for the first 10 days of March 2015.

Note: The exchange rate used was 1 USD = 2.47 TL.

Source: Acar (2015); Chambers of Agricultural Engineers (2015); Chamber of Civil Engineers (2015); Chamber of Forest Engineers (2015); Chamber of Mechanical Engineers (2015); Energy Market Regulatory Authority (2015); Social Security Institution (2015); Water and Sewerage Authority General Directorate (2016)

TABLE 56.

Energy demand per household

	RURAL HOUSEHOLDS		URBAN HOUSEHOLDS	
	MARKET PRICE (USD/KG)	CONSUMPTION (KG/DAY/HH)	MARKET PRICE (USD/KG)	CONSUMPTION (KG/DAY/HH)
Briquettes	0.14		0.14	
Fuelwood	0.15	2	0.15	1.70
Charcoal	1.21	1.5	1.21	0.59
Kerosene	1.30		1.30	
LPG	2.34	0.54	2.34	1.17
Coal	0.28	2.02	0.28	1.59
Natural Gas	0.41	0.30	0.41	0.04
Electricity	0.13	350		

Note: The exchange rate used was 1 USD = 2.47 TL

Source: Acar (2015); Confidence Charcoal Depot (2015); Energy Market Regulatory Authority (2015); Factfish (2015); Fatih Mining (2015); IGDAS (2015); IPRAGAZ (2015)

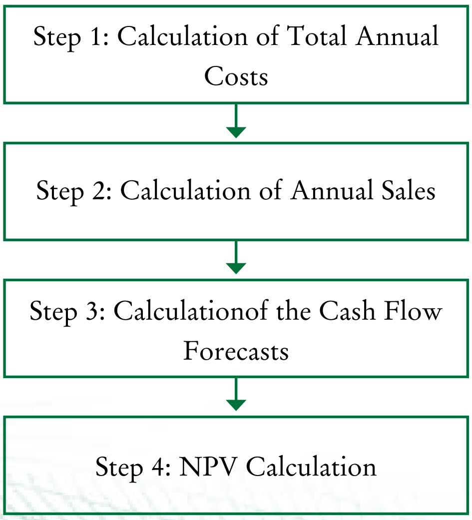
5. EXAMPLE OF THE FINANCIAL CALCULATIONS

This section presents an example of how the Net Present Value (NPV) was estimated within the techno-economic component of the BEFS assessment. The example used to illustrate the approach is that of the briquettes end use options. As explained in the report, the NPV was the basis of the maximum feedstock price calculations and the generation of profitability zones maps used to define profitable production conditions for the feedstock analysed in the assessment.

The NPV calculation comprises the following steps:

FIGURE 81.

Steps for calculating the NPV



Considering the above steps, calculations were performed over three of the different ranges of analysis previously defined in this report. These ranges include energy potential of feedstock (10 – 20 MJ/kg), feedstock costs (0-150 USD/t) and plant sizes (4 kg/h, 40 kg/h, 400 kg/h, 4 000 kg/h). The tables included below present the results obtained in each step. Results of each of these steps are presented according to the three ranges used as variables.

STEP 1: TOTAL ANNUAL COST (USD/YEAR)

Table 57 presents the results of the calculation for step 1, namely the calculation of the total annual costs in USD/year, for briquettes. The tables shows the total annual cost considering an energy potential range of 10 to 20 MJ/kg, a feedstock cost of 0 to 300 USD/t and four plant capacity sizes.

TABLE 57.

Total annualized cost of briquettes production at different production capacities and energy potentials of feedstock

		TOTAL ANNUAL COST (USD/YEAR)			
ENERGY POTENTIAL (MJ/kg)	FEEDSTOCK COST (USD/t)	4 kg/h	40 kg/h	400 kg/h	4 000 kg/h
10	$0	$742	$8 052	$109 942	$1 051 134
13	$0	$742	$8 052	$109 942	$1 051 134
15	$0	$742	$8 052	$109 942	$1 051 134
18	$0	$742	$8 052	$109 942	$1 051 134
20	$0	$742	$8 052	$109 942	$1 051 134
10	$150	$2 258	$23 210	$413 100	$4 461 660
13	$150	$2 258	$23 210	$413 100	$4 461 660
15	$150	$2 258	$23 210	$413 100	$4 461 660
18	$150	$2 258	$23 210	$413 100	$4 461 660
20	$150	$2 258	$23 210	$413 100	$4 461 660
10	$300	$3 773	$38 367	$716 258	$7 872 186
13	$300	$3 773	$38 367	$716 258	$7 872 186
15	$300	$3 773	$38 367	$716 258	$7 872 186
18	$300	$3 773	$38 367	$716 258	$7 872 186
20	$300	$3 773	$38 367	$716 258	$7 872 186

Source: All data was obtained from calculations by the authors.

STEP 2: TOTAL ANNUAL SALES (USD/YEAR)

Table 58, presents the results of the total annual sales calculation step. Results are reported by plant size, energy potential and feedstock cost. Briquettes are sold at the current market prices.[20] *The results show that as the energy potential increases, the total sales volume increases, namely feedstock with a higher energy potential can result in higher gains. This is under the assumption that briquettes produced with high energy potential feedstocks are of higher quality and more competitive.*

TABLE 58.

Annualized sales of briquettes at different production capacities and energy potentials of feedstock. Briquettes sold at their market price.

		ANNUAL SALES (USD/YEAR)			
ENERGY POTENTIAL (MJ/kg)	FEEDSTOCK COST (USD/t)	4 kg/h	40 kg/h	400 kg/h	4 000 kg/h
10	$0	$852	$8 515	$170 303	$1 436 935
13	$0	$1 064	$10 644	$212 879	$1 796 169
15	$0	$1 277	$12 773	$255 455	$2 155 403
18	$0	$1 490	$14 902	$298 031	$2 514 636
20	$0	$1 703	$17 030	$340 607	$2 873 870
10	$150	$852	$8 515	$170 303	$1 436 935
13	$150	$1 064	$10 644	$212 879	$1 796 169
15	$150	$1 277	$12 773	$255 455	$2 155 403
18	$150	$1 490	$14 902	$298 031	$2 514 636
20	$150	$1 703	$17 030	$340 607	$2 873 870
10	$300	$852	$8 515	$170 303	$1 436 935
13	$300	$1 064	$10 644	$212 879	$1 796 169
15	$300	$1 277	$12 773	$255 455	$2 155 403
18	$300	$1 490	$14 902	$298 031	$2 514 636
20	$300	$1 703	$17 030	$340 607	$2 873 870

Source: All data was obtained from calculations by the authors.

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[20] The market prices for briquettes were obtained through the data collection process work carried out in the country as described and referenced in the main body of the report.

STEP 3: CASH FLOWS FORECASTS

The following tables contain the cash flows forecasts for a 10 year period. Each tables contains the results for each of the four plant capacities analysed. The annual cash flows are obtained after subtracting the total annual costs from the total annual sales. A common practice in these calculations is to include escalation rates in costs and market prices according to the inflation rate, as well as taxes. However, the analysis represents a baseline and considers no escalation rates nor potential levies or subsidies at this stage. As a result, in the upcoming tables cash flow forecasts for year 1 to 10 are constant values. Year 0 represents the initial investment required to start-up each project. The results illustrate the impact of the energy potential and feedstock costs on the cash flow results. Annual cash flows were calculated as follows:

Annual Cash Flows=Annual Total Sales-Annual Total Costs

TABLE 59.

Cash flow forecast for briquettes sold at current market price and produced at 4 kg/h plant capacity.

ENERGY POTENTIAL (MJ/KG)	FEEDSTOCK COST (USD/T)	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
10	$0	-$1 336	$110	$110	$110	$110	$110	$110	$110	$110	$110	$110
13	$0	-$1 336	$323	$323	$323	$323	$323	$323	$323	$323	$323	$323
15	$0	-$1 336	$536	$536	$536	$536	$536	$536	$536	$536	$536	$536
18	$0	-$1 336	$748	$748	$748	$748	$748	$748	$748	$748	$748	$748
20	$0	-$1 336	$961	$961	$961	$961	$961	$961	$961	$961	$961	$961
10	$150	-$1 336	-$1 406	-$1 406	-$1 406	-$1 406	-$1 406	-$1 406	-$1 406	-$1 406	-$1 406	-$1 406
13	$150	-$1 336	-$1 193	-$1 193	-$1 193	-$1 193	-$1 193	-$1 193	-$1 193	-$1 193	-$1 193	-$1 193
15	$150	-$1 336	-$980	-$980	-$980	-$980	-$980	-$980	-$980	-$980	-$980	-$980
18	$150	-$1 336	-$767	-$767	-$767	-$767	-$767	-$767	-$767	-$767	-$767	-$767
20	$150	-$1 336	-$555	-$555	-$555	-$555	-$555	-$555	-$555	-$555	-$555	-$555
10	$300	-$1 336	-$2 922	-$2 922	-$2 922	-$2 922	-$2 922	-$2 922	-$2 922	-$2 922	-$2 922	-$2 922
13	$300	-$1 336	-$2 709	-$2 709	-$2 709	-$2 709	-$2 709	-$2 709	-$2 709	-$2 709	-$2 709	-$2 709
15	$300	-$1 336	-$2 496	-$2 496	-$2 496	-$2 496	-$2 496	-$2 496	-$2 496	-$2 496	-$2 496	-$2 496
18	$300	-$1 336	-$2 283	-$2 283	-$2 283	-$2 283	-$2 283	-$2 283	-$2 283	-$2 283	-$2 283	-$2 283
20	$300	-$1 336	-$2 070	-$2 070	-$2 070	-$2 070	-$2 070	-$2 070	-$2 070	-$2 070	-$2 070	-$2 070

Source: All data was obtained from calculations by the authors.

TABLE 60.

Cash flow forecast for briquettes sold at current market price and produced at 40 kg/h plant capacity. No escalation rate or taxes considered in analysis.

ENERGY POTENTIAL (MJ/KG)	FEEDSTOCK COST (USD/T)	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
10	$0	-$6 678	$463	$463	$463	$463	$463	$463	$463	$463	$463	$463
13	$0	-$6 678	$2 592	$2 592	$2 592	$2 592	$2 592	$2 592	$2 592	$2 592	$2 592	$2 592
15	$0	-$6 678	$4 721	$4 721	$4 721	$4 721	$4 721	$4 721	$4 721	$4 721	$4 721	$4 721
18	$0	-$6 678	$6 850	$6 850	$6 850	$6 850	$6 850	$6 850	$6 850	$6 850	$6 850	$6 850
20	$0	-$6 678	$8 979	$8 979	$8 979	$8 979	$8 979	$8 979	$8 979	$8 979	$8 979	$8 979
10	$150	-$6 678	-$14 694	-$14 694	-$14 694	-$14 694	-$14 694	-$14 694	-$14 694	-$14 694	-$14 694	-$14 694
13	$150	-$6 678	-$12 566	-$12 566	-$12 566	-$12 566	-$12 566	-$12 566	-$12 566	-$12 566	-$12 566	-$12 566
15	$150	-$6 678	-$10 437	-$10 437	-$10 437	-$10 437	-$10 437	-$10 437	-$10 437	-$10 437	-$10 437	-$10 437
18	$150	-$6 678	-$8 308	-$8 308	-$8 308	-$8 308	-$8 308	-$8 308	-$8 308	-$8 308	-$8 308	-$8 308
20	$150	-$6 678	-$6 179	-$6 179	-$6 179	-$6 179	-$6 179	-$6 179	-$6 179	-$6 179	-$6 179	-$6 179
10	$300	-$6 678	-$29 852	-$29 852	-$29 852	-$29 852	-$29 852	-$29 852	-$29 852	-$29 852	-$29 852	-$29 852
13	$300	-$6 678	-$27 724	-$27 724	-$27 724	-$27 724	-$27 724	-$27 724	-$27 724	-$27 724	-$27 724	-$27 724
15	$300	-$6 678	-$25 595	-$25 595	-$25 595	-$25 595	-$25 595	-$25 595	-$25 595	-$25 595	-$25 595	-$25 595
18	$300	-$6 678	-$23 466	-$23 466	-$23 466	-$23 466	-$23 466	-$23 466	-$23 466	-$23 466	-$23 466	-$23 466
20	$300	-$6 678	-$21 337	-$21 337	-$21 337	-$21 337	-$21 337	-$21 337	-$21 337	-$21 337	-$21 337	-$21 337

Source: All data was obtained from calculations by the authors.

TABLE 61.

Cash flow forecast for briquettes sold at current market price and produced at 400 kg/h plant capacity. No escalation rate or taxes considered in analysis.

ENERGY POTENTIAL (MJ/KG)	FEEDSTOCK COST (USD/T)	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
10	$0	-$124 372	$60 361	$60 361	$60 361	$60 361	$60 361	$60 361	$60 361	$60 361	$60 361	$60 361
13	$0	-$124 372	$102 937	$102 937	$102 937	$102 937	$102 937	$102 937	$102 937	$102 937	$102 937	$102 937
15	$0	-$124 372	$145 513	$145 513	$145 513	$145 513	$145 513	$145 513	$145 513	$145 513	$145 513	$145 513
18	$0	-$124 372	$188 088	$188 088	$188 088	$188 088	$188 088	$188 088	$188 088	$188 088	$188 088	$188 088
20	$0	-$124 372	$230 664	$230 664	$230 664	$230 664	$230 664	$230 664	$230 664	$230 664	$230 664	$230 664
10	$150	-$124 372	-$242 797	-$242 797	-$242 797	-$242 797	-$242 797	-$242 797	-$242 797	-$242 797	-$242 797	-$242 797
13	$150	-$124 372	-$200 221	-$200 221	-$200 221	-$200 221	-$200 221	-$200 221	-$200 221	-$200 221	-$200 221	-$200 221
15	$150	-$124 372	-$157 645	-$157 645	-$157 645	-$157 645	-$157 645	-$157 645	-$157 645	-$157 645	-$157 645	-$157 645
18	$150	-$124 372	-$115 069	-$115 069	-$115 069	-$115 069	-$115 069	-$115 069	-$115 069	-$115 069	-$115 069	-$115 069
20	$150	-$124 372	-$72 494	-$72 494	-$72 494	-$72 494	-$72 494	-$72 494	-$72 494	-$72 494	-$72 494	-$72 494
10	$300	-$124 372	-$545 955	-$545 955	-$545 955	-$545 955	-$545 955	-$545 955	-$545 955	-$545 955	-$545 955	-$545 955
13	$300	-$124 372	-$503 379	-$503 379	-$503 379	-$503 379	-$503 379	-$503 379	-$503 379	-$503 379	-$503 379	-$503 379
15	$300	-$124 372	-$460 803	-$460 803	-$460 803	-$460 803	-$460 803	-$460 803	-$460 803	-$460 803	-$460 803	-$460 803
18	$300	-$124 372	-$418 227	-$418 227	-$418 227	-$418 227	-$418 227	-$418 227	-$418 227	-$418 227	-$418 227	-$418 227
20	$300	-$124 372	-$375 651	-$375 651	-$375 651	-$375 651	-$375 651	-$375 651	-$375 651	-$375 651	-$375 651	-$375 651

Source: All data was obtained from calculations by the authors.

TABLE 62.

Cash flow forecast for briquettes sold at current market price and produced at 4 000 kg/h plant capacity. No escalation rate or taxes considered in analysis.

ENERGY POTENTIAL (MJ/KG)	FEEDSTOCK COST (USD/T)	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
10	$0	-$1 154 328	$385 801	$385 801	$385 801	$385 801	$385 801	$385 801	$385 801	$385 801	$385 801	$385 801
13	$0	-$1 154 328	$745 035	$745 035	$745 035	$745 035	$745 035	$745 035	$745 035	$745 035	$745 035	$745 035
15	$0	-$1 154 328	$1 104 269	$1 104 269	$1 104 269	$1 104 269	$1 104 269	$1 104 269	$1 104 269	$1 104 269	$1 104 269	$1 104 269
18	$0	-$1 154 328	$1 463 503	$1 463 503	$1 463 503	$1 463 503	$1 463 503	$1 463 503	$1 463 503	$1 463 503	$1 463 503	$1 463 503
20	$0	-$1 154 328	$1 822 736	$1 822 736	$1 822 736	$1 822 736	$1 822 736	$1 822 736	$1 822 736	$1 822 736	$1 822 736	$1 822 736
10	$150	-$1 154 328	-$3 024 725	-$3 024 725	-$3 024 725	-$3 024 725	-$3 024 725	-$3 024 725	-$3 024 725	-$3 024 725	-$3 024 725	-$3 024 725
13	$150	-$1 154 328	-$2 665 491	-$2 665 491	-$2 665 491	-$2 665 491	-$2 665 491	-$2 665 491	-$2 665 491	-$2 665 491	-$2 665 491	-$2 665 491
15	$150	-$1 154 328	-$2 306 257	-$2 306 257	-$2 306 257	-$2 306 257	-$2 306 257	-$2 306 257	-$2 306 257	-$2 306 257	-$2 306 257	-$2 306 257
18	$150	-$1 154 328	-$1 947 024	-$1 947 024	-$1 947 024	-$1 947 024	-$1 947 024	-$1 947 024	-$1 947 024	-$1 947 024	-$1 947 024	-$1 947 024
20	$150	-$1 154 328	-$1 587 790	-$1 587 790	-$1 587 790	-$1 587 790	-$1 587 790	-$1 587 790	-$1 587 790	-$1 587 790	-$1 587 790	-$1 587 790
10	$300	-$1 154 328	-$6 435 251	-$6 435 251	-$6 435 251	-$6 435 251	-$6 435 251	-$6 435 251	-$6 435 251	-$6 435 251	-$6 435 251	-$6 435 251
13	$300	-$1 154 328	-$6 076 017	-$6 076 017	-$6 076 017	-$6 076 017	-$6 076 017	-$6 076 017	-$6 076 017	-$6 076 017	-$6 076 017	-$6 076 017
15	$300	-$1 154 328	-$5 716 784	-$5 716 784	-$5 716 784	-$5 716 784	-$5 716 784	-$5 716 784	-$5 716 784	-$5 716 784	-$5 716 784	-$5 716 784
18	$300	-$1 154 328	-$5 357 550	-$5 357 550	-$5 357 550	-$5 357 550	-$5 357 550	-$5 357 550	-$5 357 550	-$5 357 550	-$5 357 550	-$5 357 550
20	$300	-$1 154 328	-$4 998 316	-$4 998 316	-$4 998 316	-$4 998 316	-$4 998 316	-$4 998 316	-$4 998 316	-$4 998 316	-$4 998 316	-$4 998 316

Source: All data was obtained from calculations by the authors.

STEP 4: NPV CALCULATION

In step 4 the cash flows forecasts are then used to calculate the NPV. The NPV equation presents the cumulative value (revenues –expenses) adjusted to the reference time, where the term (1+i)n is the discount factor, i.e., the discount rate. As explained in the report, for bioenergy projects an acceptable discount rate range is 9-11 percent.[21]

$$NPV = \sum_{i=0}^{n} \frac{Annual\ Cash\ Flows}{(1+i)^n}$$

TABLE 63.

Net Present Value of briquettes sold at their current market price. Discount Rate 9 percent.

		NET PRESENT VALUE (USD/year)			
ENERGY POTENTIAL (MJ/kg)	FEEDSTOCK COST (USD/t)	4 kg/h	40 kg/h	400 kg/h	4 000 kg/h
10	$0	-$631	-$3 704	$263 004	$1 321 613
13	$0	$735	$9 958	$536 241	$3 627 053
15	$0	$2 101	$23 620	$809 478	$5 932 492
18	$0	$3 467	$37 282	$1 082 716	$8 237 931
20	$0	$4 834	$50 944	$1 355 953	$10 543 371
10	$150	-$10 359	-$100 982	-$1 682 560	-$20 565 977
13	$150	-$8 993	-$87 320	-$1 409 323	-$18 260 538
15	$150	-$7 627	-$73 658	-$1 136 085	-$15 955 099
18	$150	-$6 260	-$59 996	-$862 848	-$13 649 659
20	$150	-$4 894	-$46 334	-$589 611	-$11 344 220
10	$300	-$20 087	-$198 260	-$3 628 123	-$42 453 568
13	$300	-$18 721	-$184 598	-$3 354 886	-$40 148 128
15	$300	-$17 354	-$170 936	-$3 081 649	-$37 842 689
18	$300	-$15 988	-$157 274	-$2 808 412	-$35 537 250
20	$300	-$14 622	-$143 612	-$2 535 174	-$33 231 810

Source: All data was obtained from calculations by the authors.

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[21] Committee on Climate Change, Biomass in power generation. Bioenergy Review, Technical Paper 4, 2011. Available from: www.theccc.org.uk/archive/aws2/Bioenergy/1463%20CCC_Bio-TP4_power_FINALwithBkMks.pdf.

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ENVIRONMENT – CLIMATE CHANGE – BIOENERGY – MONITORING AND ASSESSMENT
FAO - ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

Turkey has a large agriculture sector and relies on imported fossil fuels for a significant portion of its domestic energy supply. In order to address energy security and as part of their climate change strategy, Turkey has established a set of renewable energy targets. Given the size of the agriculture sector, there is interest in understanding if agriculture residues can play a role in meeting the renewable energy target, as part of the bioenergy component of renewable energy. This report provides an initial assessment of the potential availability of crop and livestock residues and of the technical and economic potential to produce heat and power from these residues. The set of bioenergy technologies analyzed are briquettes, pellets, and large-scale combined heat and power from direct combustion and biogas. The analysis was carried out at provide level, using country specific data and national technical inputs. Results of the assessment illustrate the degree of bioenergy potential on at province level, and consequently, which provinces are best suited to the identified bioenergy supply chains. The report quantifies to what degree the selected bioenergy supply chains can achieve the renewable energy targets for biomass and also the amount of household level energy needs that could be generated from briquettes and pellets. In the conclusions, it is underscored how accessibility and mobilization of biomass remain one of the main hurdles to unlocking the full bioenergy potential estimated.

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