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Effects of the Renewable Energy Act on structural change in Agriculture – The case of biogas

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Abstract.

Biogas production affected agricultural and land markets significantly. This paper provides insights in effects of biogas production on farms and farm structures for the period 2012-2026 in two German regions by using the agent-based simulation model AgriPoliS. We compare the agricultural development in both regions under alternative policy scenarios in order to analyze the effects of biogas production and the impact of the latest amendment in the REA in 2014. Our results show that biogas production provides especially for large farms a profitable income opportunity. However, it implies an increasing dependency of these farms on biogas production and their whole production structures change. Due to an increased competition among farms, rental prices rise. This effect threatens particularly smaller biogas farms. The last amendment of the REA in 2014 with a substantial reduction of the support level attenuates partly some of these effects.

Keywords: biogas production, agent-based modelling, Renewable Energy Act, EEG 2.0

JEL codes: Q15, Q18, Q42, C69

1. Introduction and Background

Biogas production is one of the most influential innovations of recent decades in German agriculture. Supported by guaranteed feed-in tariffs and priority connection to the electricity grid regulated by the Renewable Energy Sources Act (EEG) (AEE, 2012b) farms were able to rapidly adapt to the new opportunities. Between 2006 and 2011 the total number of plants doubled while the capacity even increased to more than two-and-a-half times. In 2011, more than 7,000 biogas plants with an average plant capacity of 402 kW produced renewable energy in Germany (AEE, 2012a).

Because of the guaranteed feed-in tariffs for 20 years, investments in biogas plants promise to be secure and very profitable for farmers. On the other hand, the high profitability leads to new dynamics on land markets. Several studies show that the higher the biogas production in a region the stronger is the increase in land purchase and rental prices. For example, Braun et al. (2007) found that biogas producers in North Rhine-Westfalia (West Germany) have a much higher willingness to pay for arable land and especially grazing land than crop producing farmers. Kilian et al. (2008) find that high shares of biogas production led to higher rental prices in Bavaria. Habermann and Breustedt (2011) detect differences of impacts of biogas production between West and East Germany. They examine in their spatial econometric analysis that "agricultural biogas production, measured as the share of acreage cultivated with energy crops, increases the rental rates in Western Germany significantly" (Habermann and Breustedt, 2011), but that does not hold for Eastern Germany. Habermann and Breustedt explain the insignificance in East Germany by referring to the average larger size of East German farms, which causes less pressure to rent land for growing biogas substrates. In a more recent study, Hüttel et al. (2012) demonstrate that biogas production measured in kW per sub-district has a significant positive impact on sales prices of auctioned land in Saxony-Anhalt, East Germany. As an interim summary, effects of biogas production on land rental markets may vary for different regions and farm sizes. Nevertheless, increases in rental prices might be at least partly driven by biogas producers as they need feed for their biogas plants and are able to bid high prices for land because of the high guaranteed feed-in tariffs. Finally, biogas production may also lead to a different production structure of farms. Feed and food production are increasingly displaced by renewable energy crops such as maize and ley. Furthermore manure is a cheap co-substrate, but it needs cattle and therefore also feed.

While impacts of biogas production on land markets and, thus, farm competition with regard to rental prices have been analysed in the past, impacts on farm competition and cultivation with focus on East German agriculture are underrepresented. The present paper seeks to fill this gap by

studying impacts of biogas production on one East German region, namely the Altmark. For reasons of comparability we do the same simulations also for the Ostallgäu (OAL) as one representative of Western German regions. Both regions have an agricultural sector with a high proportion of specialized dairy farms and grassland and therefore a huge potential of biomass from several sectors.

The development in the bioenergy market is policy driven. Therefore, the market conditions and developments are affected as the demand for biogas is raised artificially through the guaranteed feed-in tariffs. Long-term effects are difficult to be estimated exactly. Therefore, reservations and discussions exist on the side of the non-biogas farmers who fear for their (future) competiveness particularly on the land market, as well as on the side of the biogas farmers who are concerned about the stability of political decisions. This is embedded in a public discussion on impacts of biogas production on environment and quality of life in rural areas. As one result of such discussions and concerns the Renewable Energy Act was amended several times since 2000. The latest change, the so-called "EEG 2.0"[1] resulted in a substantial reduction of the guaranteed feed-in tariffs. In this paper we therefore also analyse the long-term effect of such political reforms.

The present paper analyses in the first place impacts of biogas production and energy policy on agriculture. As we focus rather on the structure of farms and agricultural regions than on markets, we concentrate on two aspects: Firstly, on the competitiveness of production activities within a farm (we call this in-farm competition) and second on the competitiveness of farms within a region (we call this inter-farm competition). Differently from other studies we use in our analysis an agent-based simulation model, namely AgriPoliS, which enables ex-post analyses of agricultural structural change and the impact of policies on agriculture. The simulation results enable to examine in-farm competition by comparing revenue shares of production branches, as well as cultivation sizes and livestock keeping. Besides, we analyse profits of biogas and non-biogas farms, rental prices for arable and grazing land as well as farm size developments and rental prices which represent the inter-farm competition. As far as it is possible, we compare our simulation results with the development in reality.

The paper proceeds as follows. The next section introduces the agent-based model AgriPoliS together with the case study regions Altmark and OAL. In section 3 simulation results for a time period of 15 years are analysed and discussed. Finally, section 4 provides a conclusion.

[1] EEG: Erneuerbare-Energien-Gesetz (in English: Renewable Energy Act)

2. Methodological approach and case study region

To analyse the impact of biogas production we use the agent-based model AgriPoliS (Agricultural Policy Simulator, e.g. Happe et al., 2006). In this chapter we describe the model features and the study regions Altmark in East Germany and OAL in West Germany.

2.1. The agent-based model AgriPoliS

AgriPoliS is an agent-based model which enables to simulate regional agricultural structures and their developments over time in response to different policies (see Happe, 2004; Happe et al. 2008, Sahrbacher et al. 2012a). A detailed documentation of the current version can be found in Kellermann et al. (2008), and a protocol following the ODD standard (Overview, Design concepts and Details) is available in Sahrbacher et al. (2012b).

In AgriPoliS a number of individual agents acts and also interacts in an environment which maps agriculturally related regional and structural characteristics. First, the region has to be initialised by adapting the model to the real region. This happens on two levels. On the one hand, statistical data about regional agriculture and data of individual farms (usually data from the farm accountancy data network (FADN)) are used to map the regional characteristics of agriculture regarding number of farms, farm types and farm orientations, amount of arable and grazing land, number of livestock in the region, size classes in hectares and number of livestock per farm. In a programming approach based on the method of Balmann et al. (1998) and further developed by Sahrbacher and Happe (2008), typical farms are identified from a large number of individual farms. By minimizing the deviation between the sum of the weighted characteristics of individual farm types and the overall characteristics of the region, it is determined how often the different farm types should be weighted to map this region as accurately as possible. Apart from a farm's factor endowment and size, farms differ in the management skills, which influence the variable costs of production processes, and in the age of machinery, buildings. The management skills and the ages are varied randomly to ensure heterogeneity among agents.

On the other hand, the organization, i.e. possible production processes and investments, of the selected typical farms is projected by adapting model farms to the selected real farms. Therefore, a linear programming model is built, in which the selected typical farms' data on factor endowments (quota, facilities, labour, capital, land, etc.) is incorporated. Furthermore, various production and investment alternatives are entered, from which the farms can choose to optimally utilize their factor endowments. All options must be typical for the region and are calibrated such that in the beginning of each simulation, the derived model farms choose nearly the same production processes

as the real farms they represent. For the different types of production, each farm can choose between a number of investment alternatives of different size to capture size effects due to decreasing investment costs and labour requirements per unit.

Besides deciding on products and investments, farms can also extend their capacities by renting agricultural land, buying production quotas, and employing workers. Furthermore, capital can be borrowed on a short- and long-term basis. In contrast, capacities can be set free, e.g., land rental contracts can expire, quotas can be rented out, hired labour can be dismissed or family workers can be employed outside the farm. Furthermore, liquid assets may be invested outside the farm. All decisions on production, investment and redundancy of capacities are based on a one period mixed-integer programming. In case of renting land farms compete for free land via an auction on the land rental market. Generally, it is assumed that each farm operates independently to maximize its individual household income or profit in case of legal persons. The resulting decision behaviour of the agents is rational, but myopic. Strategic decisions considering future changes in the technical and economical conditions are currently not included in the model. Farms are assumed to expect constant environmental conditions for future periods and adjust their price expectations adaptively from period to period. Policy changes are anticipated one period in advance and included in the decision. Finally, farms can also leave the sector if they are illiquid or expect a lack of coverage of opportunity costs.

2.2. Case study regions

The first study region is the Altmark region with its two districts Stendal and Altmarkkreis Salzwedel. The Altmark is located in the German Federal State of Saxony-Anhalt, approx. 50-150 km west of Berlin. Being characterized by large arable farms as well as large mixed farms with livestock, Altmark is a good representative of East German agricultural regions. The importance of livestock production is emphasized by the fact that around 40 % of the dairy cows and 53 % of the specialised dairy farms in Saxony-Anhalt are located in Altmark (in 2007, StaLa, 2008). In addition, the proportion of grassland is comparatively high (nearly 27 %).

The second study area is located in the district of Ostallgäu (OAL) in the south of Bavaria. The landscape structure of mainly pre-Alpine terrain is bounded on the south by the Allgäu Alps. The present analysis is focused on only one part of the district which is relatively homogeneous in terms of geographic events and climatic conditions. The selection was made taking into account regional statistical data and expert knowledge of the Office of Nutrition, Agriculture and Forestry (AELF) Kaufbeuren (AELF Kaufbeuren, 2010). The 13 selected communities have a very high proportion of grassland. Only 4% of the total UAA is used as arable land (Statistische Ämter des Bundes und

der Länder, 2012d). The excluded communities north of Kaufbeuren are more characterized by arable farming. Overall in 2007 the 27,117 ha UAA in the selected communities were maintained by 1,057 farms. 844 of them hold a total of 25,499 dairy cows. The farm size is much more homogeneous than in the Altmark. Relatively small farms with less than 30 ha predominate in Ostallgäu. Most dairy cows are in herds of 30-49 animals. Beef cattle and suckler cows are less common. In addition to beef cattle, there is hardly any other livestock in the study area.

Both study regions are predestined for biogas production. Since 2009 the Altmark is one of 25 so-called bioenergy regions (BMELV, 2012) in Germany, because it offers a huge potential of biomass from several sectors. In the long run, one aim of this initiative is to generate regional value added by the extension of bioenergy production to support sustainable developments of rural areas (Regionale Planungsgemeinschaft Altmark, 2012). With a high proportion of specialized dairy farms and grass land, agriculture provides many possible usages of biomass for energy production, e.g. biogas. Many farms already invested in biogas production in recent years: in 2012 a total number of 107 biogas plants produced 364 GWh electrical energy (Landtag von Sachsen-Anhalt, 2014). Besides many positive synergy effects of biogas production regarding, e.g., energy recovery in local households there are also critical voices in society concerning the building of biogas plants. In a SWOT analysis of the “bioenergy-region Altmark“, Regionalverein Altmark e.V. (2008) mentioned acceptance problems in the public as well as conflicts, fears or resistance on local level which may prevent the implementation of bioenergy projects. However, there is less potential for conflicts in the field of biogas compared to other areas of renewable energies such as wind power plants. Despite all prejudices and reservations against bioenergy, there have not been any serious conflicts in the Altmark so far. Problems with existing biogas plants have only concerned individual cases. But from the perspective of nature and environmental protection, there are more and more critical arguments against further extension of bioenergy, such as negative effects due to ploughing up of grassland, cultivation of agricultural monocultures and increasing pressure on the use of sensitive areas (cf. Regionalverein Altmark e.V., 2008).

Also the OAL as a region with focus on grassland and livestock is predestined for biogas production. The distribution of biogas plants in Bavaria (LFL 2006a) shows a significant investment concentration in the cattle-growing regions Swabia and Allgäu, Bavaria Central Franconia and Southeast. Currently, 74 biogas plants are operated in the OAL (LFL 2014).

2.3. Modelling the regions in AgriPoliS

To capture the regional agricultural structure as good as possible, typical farms for the representation and their weights have to be identified as described in section 2.1. Therefore, most

recent available statistics on regional agricultural characteristics (e.g. number of farms, livestock, farm size classes etc.) and FADN data of regional farms are used (cf. Balmann et al., 2010). Because agricultural statistics were last available for 2007, we also used FADN data for 2006/07 and start simulations in 2006. The up-scaling procedure resulted in 33 typical farms for the Altmark which represent with their weights 968 model farms. For the OAL 16 typical farms represent 962 model farms. The model farms differ in their type of farm, available capacities, management capabilities, which influence their variable costs, and in the age of machinery and buildings.

Model farms are able to produce crops and livestock. The assumptions for those different production processes come from data bases of contribution margins of crops (LLFG, 2009) as well as feed and livestock (MLUV, 2008; LFL 2006 and 2014). The reference year to which the regions are calibrated is the financial year 2006/07.

Focus of this paper is biogas production. Thus, biogas production is introduced in the model. Farms can choose between different options of plant sizes and substrate mixtures. Overall, three plant capacities for each region (150, 450, 800 kW for Altmark and 70, 125, 200 kW for OAL), and three mixtures with different shares of maize and grass silage, liquid cattle manure, and rye grain are offered. In the OAL region the maize silage is purchased by the farms, as they cannot grow maize themselves due to the lack of arable land in the region. Table 1 shows the assumptions on the biogas plants with their revenues from feed-in tariffs, the investment and calculated substrate costs as well as the needed working time to operate the plant. The investments costs per kW are assumed to decrease with increasing plant size. Investment and production data for biogas production were taken from KTBL (2010); the guaranteed feed-in remuneration, consisting of a basic payment and bonuses, is based on the RAE 2009 and 2012 (BMJ, 2008, 2010 and 2011).

In reality the basic remuneration is oriented towards the time of building of the biogas plant. Accordingly, a plant built later receives lower basic feed-in tariffs. For simplification we did not consider such a dynamic degression of feed-in tariffs. Background is that in reality not only remuneration would decrease but it can also be assumed that investment costs decrease because of efficiencies, e.g., by up to 5 % according to Prognos AG (2010). Therefore, we assume constant remunerations during the period 2012 to 2026 according the EEG. Both, the decreasing investment costs and degressive remuneration would in reality more or less neutralize each other. Furthermore, we have not implemented a minimum use of lost heat so far.

In reality the Renewable Energy Sources Act changed several times. This is considered in the model as well. From 2006 to 2012 the former EEG 2009 is applied, from 2012 assumptions shown in Tables 1 and 2 are considered. The main difference of the EEG 2012 to the EEG 2009 lies in the

allowed shares of substrates. In 2012 a maximum limit of 60 % of maize silage, corncob mix and grain kernel was introduced. This limitation is also used in the model as can be seen in Table 2. From 2012 on, farms can choose between three mixtures to produce biogas. With Mix 3 it is even possible to operate a biogas plant without cattle manure. More common in reality is the use of manure and maize silage (see Mix 1 and Mix 2). The latest change of the renewable energy act in 2014 (EEG 2.0) results mainly in decreasing feed-in tariffs (see Table 3).

To illustrate the effects of biogas production, we compare two biogas scenarios with a REFERENCE scenario. In the REFERENCE scenario farms cannot invest in biogas plants while in the biogas scenarios biogas production is available. In all scenarios, farms have the same conditions apart from the availability to invest in biogas plants in the two biogas scenarios. To examine the latest change of the EEG in 2014, we compare two biogas scenarios. The difference between them is the application of the latest EEG change. In the EEG 2.0 scenario the feed-in tariffs decrease from 2014 on according to latest amendment of the renewable energy act in 2014.

No model farm has been given a biogas plant as capacity in the beginning of simulations, i.e. in 2006, because the most substantial growth began first in 2005/06 after the EEG was revised, and statistical data about existing biogas plants in the Altmark region in 2006 were not available.

3. Results and Discussion

We analyse impacts of biogas production in the Altmark and Ostallgäu regions while focusing on two aspects: 1) the choice of production of farms, and 2) the competition for land between farms. With the agent-based model AgriPoliS we simulate three scenarios, each with 100 repetitions: one biogas scenario “EEG” where the EEG is applied, a hypothetical REFERENCE scenario where no farm has the opportunity to produce biogas and a second biogas scenario “EEG 2.0” where the latest change of the renewable energy act in 2014 is considered. Simulations start in calendar year 2006. Our analyses were made for the period 2012 to 2026.

3.1. In-farm competition

Before we present results regarding the choice of production of farms, we introduce characteristics of biogas and non-biogas model farms in 2012 (Table 4).

In general, not every farmer is able to invest in a biogas plant. Size and capital are prerequisites to invest and succeed. Biogas farms are on average larger than non-biogas farms. In terms of European size units (ESU) biogas farms are nearly 1.8 times as large as other farms in the Altmark region. In

the OAL region they are even 2.5 times larger. In terms of farm size in ha they are around 4 (resp. 6 in OAL) times higher, keep much more dairy cows, and have because of their size more equity capital.

In the “EEG” scenario in 2012, 90 of the 730 model farms (i.e. 12 %) own 174 biogas plants with a total capacity of 32 MW in the Altmark region. That means every biogas producing farm owns on average 2 biogas plants in the model with an average installed capacity of 185 kW per plant or 356 kW per farm. In the OAL region there a much less biogas farms. Only 4 of the 928 model (0.4%) own biogas plants with a total capacity of 639 kW. The lower level of biogas production in the OAL region is mainly due to the fact that the farms have no arable land to cultivate maize as feed for their cattle as well as substrate for their biogas plants. They have to purchase maize silage.

Compared to reality, model farms invest in more but smaller biogas plants. This is due to the fact that model farms can neither choose intermediate sizes, e.g., between 150 and 450 kW nor cooperate and share facilities. Furthermore, model farms do not have the opportunity to buy substrates from other farms yet (except for maize silage in the OAL region). Therefore, model farms’ sizes are mostly too small to invest in larger plants. The smallest farm which invests in a biogas plant manages 315 ha and 720 dairy cows in the Altmark, and 74 ha and 195 dairy cows in the OAL. Thus, the simulation results underestimate the developments in reality. For example in 2012 in the Altmark region the installed capacity was around 48 MW (Landtag von Sachsen-Anhalt, 2014) while in the model the plants have an installed capacity up to 40 MW (mean 31 MW) depending on the repetition.

Figure 1 shows the further development of biogas farms and their total installed capacity between 2012 and 2026 in the model. Accordingly, model results support expectations that biogas production will increase further, in particular due to a rise in the installed capacity per farm. During the simulations, farms grow because others quit farming. This offers potentials to invest in larger plants as well. The almost stable number of farms, while at the same time increasing installed capacity, indicates rising plant sizes in the Altmark. Starting in 2012 with an average installed capacity of 31 MW, biogas farms increase their capacities to 89 MW per farm in 2026. The picture in the OAL region is a little bit different. Here not only the average installed capacity increases from 0.6 MW to over 6 MW, but also the number of biogas producing farms increases by almost 10 times during the simulation period. The critical size at which a farm can invest in biogas must be achieved first.

Due to these developments the structure of the farms’ production changed. According to Brendel (2011) one megawatt electrical power requires about 550 ha of energy crops. Furthermore, the

cultivation of energy maize needs much grassland as well as fallow and abandoned land (Brendel, 2011). The simulation results support this. The amount of fallow land decreases and cultivation of maize increases (see Fig. 2). Furthermore, the use of grassland is intensified as the usage changes from meadows to grass silage. Due to the lack of arable land in the OAL region only the intensified grassland use is observable. At the same time we observe a strong increase in the purchase of maize silage. In 2020 it is 7 times higher than in the REFERENCE scenario. In the Altmark only the increase in suckler cows hinders a stronger decrease of meadows and even higher intensification. But grass and maize silage are not only cultivated for direct use in the biogas plants. To use liquid manure for bioenergy production, more cows are kept in the biogas scenario (see Fig. 3) and demand grass and maize for feed as well. Also Ehrenstein et al. (2012) see this connection: Because maize is predominantly cultivated as feed, an increase in livestock may lead to a higher maize production.

Biogas producing farms do not only change their production because of the demand of the biogas plant but also increase their dependency from biogas revenues. Fig. 4 shows the composition of average revenue per ha of various farm types in the EEG scenario. At first it can be shown that revenue per ha differs highly between farm types in the Almark: arable farms have with 1,465 Euro/ha on average the lowest, arable farms with biogas production (other biogas farms) with an average 2,592 Euro/ha the highest revenue. Interesting is, furthermore, the contribution of farm branches to the revenue. The dependence on direct payments varies between 12% (other biogas farms) and 25% (arable farms). Compared to feed farms without biogas production, feed farms with biogas production have higher revenues from cattle production, and additionally the revenues from biogas production. Furthermore, the dependency on revenues from crop and pig production of feed biogas farms (feed farms with biogas production) is reduced while biogas production contributes 34% to total revenues of those farms. In case of other biogas farms, biogas production makes up 23% of the total revenue while pig and sows production contributes 37%.

In the OAL region the overall revenues per ha are higher than in the Altmark. However, also here the dependency from biogas production is shown. Over 35% of the total average revenue of biogas farms comes from biogas production.

Summing up, farms with biogas production gain a main part of revenues from this new branch. Not only revenues absolutely increase in biogas producing farms, also the composition of total revenue changes on average compared to similar farm types such that biogas production takes over a big part of revenue contribution.

Overall, the introduction of biogas production affects the in-farm competition of the different farm branches significantly. Because of the complementarity, biogas production offers synergies for cattle production, but at the same time there are competitive effects for other production activities which are substituted. Due to the fact that land is scarce and the biogas plant has to be fed constantly with maize and/or grass silage, a biogas farmer has to reorient his production to the crops which deliver more biomass per ha to avoid feed bottlenecks. That results in both, reality and model to intensification: fallow land and extensive use of grassland decrease while maize cropping and production of grass silage increase.

3.2. Inter-farm competition

Biogas plants have to be fed with energy crops (maize and grass silage) and manure from livestock which also needs feed. Thus, biogas farms need land. At the same time, the total amount of land is limited and can only in rare cases be expanded in Germany. Thus, biogas increases competition for land and land (rental) prices might rise. That possibly affects the whole structure of agricultural regions as smaller and less competitive farms quit. Furthermore, biogas farms are not only heavily dependent on land; they may also receive high remuneration payments for delivered energy. Hüttl (2012) stated that because of the high feed-in remuneration for electricity from biogas, in some places the food production oriented agriculture is already displaced by the new energy producers. According to Brendel (2011) these high remunerations cause that traditional farmers may lose rental contracts after expiring to biomass plant operators because the latter can offer higher prices per hectare.

Our simulation results confirm the advantage of biogas producers: the average rental prices for rented arable and grazing land of those farms which produce biogas in the EEG scenario are higher in the EEG scenario than in the REFERENCE scenario (Fig. 5 and 6). At the same time non-biogas farms have to pay in both scenarios nearly the same (see Fig. 5 and 6).

Furthermore, Fig. 5 shows that prices for rented arable land of biogas farms are also higher in the REFERENCE scenario. I.e., farms which invest in biogas production have in both scenarios a higher ability to pay more for land. Therefore, part of the increase in the rental prices must be independent from the development of biogas production. During simulations less successful farms exit and allow the remaining well-off farms to grow. That leads in both scenarios to increased rental prices of their farms.

In general, rental prices for land have an impact on the resulting profits of a farm. The more money is forwarded to the land owners, the less money remains for the farmer. Indeed, our simulation

results show that some biogas producing farms can increase their average profits between 2012 and 2026 compared to the REFERENCE scenario (see Fig. 7). Those benefitting biogas farmers have generally better management capabilities and are larger in hectare size than less successful biogas producers. However, Figure 7 shows as well, that not all biogas farms benefit. Quite some biogas farms lose profits. In comparison to biogas farmers who gain in the biogas scenario, the losing biogas farmers have on average lower management capabilities and are smaller. After investing in a biogas plant they are highly dependent on land to produce substrates for feeding the biogas plant. Because of the high competition for land and the resulting increases in rental prices, these biogas farms lose their initial advantage from biogas. This finding is also supported by Figure 8. Accordingly, the variance of the biogas farms' profits increases significantly compared to the same farms' profits in the REFERENCE scenario. This means that competition diminishes the potential profits of biogas very quickly. Only those farms with a real comparative advantage benefit while other investors even lose. The OAL region biogas farms have to purchase their maize silage. Therefore biogas production is less depending on the land, and the competition between the farms is lower. Therefore, initial advantage remains although the variance of the biogas farms' profits is increasing, too.

Interestingly, Figure 7 shows for the non-biogas farms in contrast no clear disadvantage in the EEG scenario. Some of them even increase their profits per ha as well as on the farm level. However, in general, total profits of surviving biogas farms are much higher (up to 414 thousand Euros per farm in the OAL, depending on the repetition). This applies also to farm size: biogas farms have more land than non-biogas farms (cp. Fig. 9).

Fig. 9 also shows that all farms in the Altmark with more than 1,000 ha produce biogas. One explanation for that is that a minimum size is needed to be able to feed a biogas plant with enough substrates. In the OAL this critical farm size is much lower due to smaller biogas plants and the possibility of purchasing maize silage. However, in both regions only large farms have enough capital and resources to build and feed biogas plants. Once invested, biogas farms have the potential to grow faster than other farms because they generate additional money with biogas production and bid higher rents on the land market. The model results show that indeed farms with biogas production grow in the EEG scenario by ca. 47 % to 1720 ha on average between 2012 and 2026 while non-biogas farms even decrease their size on average by ca. 9 % down to ca. 251 ha on average in the Altmark. In the OAL region it is different. Here also the biogas farms are bigger, but they only grow by 11% up to 195 ha on average while non-biogas farms increase their size by 43 % up to 40 ha on average.

The cause is the generally stronger structural change in the OAL. Between 2012 and 2026 43% of the farms close (in the Altmark around 30%). This provides opportunities to grow not only for biogas farms. In addition, the proportion of biogas producing farms is generally lower than in the Altmark, so that the competition to the non-biogas farms is not as heavy as in the Altmark.

In the following, we analyze the stability of farms using the equity ratio to compare the risk of insolvency of biogas and non-biogas farms. A high share of equity can help to cover losses and survive in low price periods. On the other hand it should be considered that a reduction of the equity ratio and a simultaneous increase of profits lead to a rise in return of equity (leverage effect). In general, the farms which invest in biogas plants during simulations have a lower equity ratio than other farms in both scenarios and both regions. That means biogas farms are less stable than other farms. Biogas farms even worsen their stability when investing in a biogas plant: they have an even lower equity ratio in the EEG scenario than in the REFERENCE scenario (cp. Table 5), where the same farms are not able to invest in a biogas plant. That comes as no surprise, given the fact that the investment costs are very high and require a large amount of loan capital.

As mentioned before, borrowing capital offers possibilities to increase the return of equity when a farmer can increase profits as well. In contrast, the simulation results show that biogas farms are on average not able to increase their profitability in the biogas scenario compared to the REFERENCE scenario. This holds also regarding the return of equity (Table 5).

Summing up, biogas farms are highly dependent on how successful they manage their biogas plants. The potential benefits of high feed-in tariffs result in strong competition among farms. As a result, biogas producing farms pay on average higher rents, they increase the amount of debt capital and have to pay interest for these debts. Thus, instability of biogas farms in the EEG scenario is higher. The comparative advantage of biogas within the farms' production opportunities has a strong impact regarding the question whether a farm benefits from biogas compared to a scenario without this opportunity.

3.3. Effect of the EEG 2.0

The development in the bioenergy market is policy driven. Therefore, the market conditions and developments are distorted as the demand for biogas is raised artificially through the guaranteed feed-in tariffs. Long-term effects are difficult to be estimated exactly. As we have shown in our simulation, biogas farms gain a main part of revenues from this new branch which means that also the dependency of farms on the biogas production, specifically on the guaranteed feed-in tariffs and therefore on political decisions is growing. Therefore, reservations and discussions exist on the side

of the non-biogas farmers who fear for their (future) competiveness particularly on the land market, as well as on the side of the biogas farmers who are concerned about the stability of political decisions. As indicated in the previous two chapters, since the introduction of the EEG, the biogas production has a significant impact on agricultural structures. Additionally to the effects on the agricultural and land markets, there are not inconsiderable sums of money for the guaranteed feed-in tariffs. To guide the development of wind turbines, solar power plants and biogas plants on track and to keep electricity prices in check for consumers, the EEG was reformed in 2014 under the name “EEG 2.0”. In particular, the funding rates were adjusted (cf

Table 3). In this chapter we analyze, how far the EEG 2.0 can mitigate the agricultural structural effects of the EEG.

In fact, the expansion of biogas production stagnated through the introduction of the EEG 2.0 in the two study regions (see Fig. 10). In the Altmark the number of biogas plants is even declining as there are slightly more farms exit than in the EEG scenario. In the OAL one observe a slight increase instead, whereby one must note the much lower starting level of biogas producing farms. In the Altmark no new investments in biogas plants are realized after 2014. The installed capacity for the whole region remains constant for several years due to the operational time of the existing biogas plants. In 2026 we observe a decrease of the installed capacity, because the first biogas plants (built in 2006) are running out.

Also the cultivation patterns (Fig. 11 and Fig. 12) show significant effects. This is not a simple development towards the REFERENCE situation. The initial investment in biogas plants have a long-lasting effect, which is due to the operational time of biogas plants of 20 years. As in OAL investments in biogas plants are initially low and only slowly increasing in the course of time under EEG conditions (from about 2016/2017), here the production structure in the EEG 2.0 resembles very strong to the REFERENCE situation. The only observable difference in the land use is a drop in grass silage production in favor of meadows. The situation in the Altmark is somewhat different. At the beginning of the analyzed period a number of biogas plants are in operation. Rather than stagnation as in OAL, the number of biogas-producing farms reduces over time. That has a long term effect on the cultivation patterns. Figure 11 show that farms now produce more cash crops. The areas for maize and grass silage decrease. Except for milk production, cattle are declining.

The effects of biogas production on rental prices are mitigated partly by the EEG 2.0 in the first years (cp. Fig. 13 and Fig. 14). Due to the reduced guaranteed feed-in tariffs, biogas farms cannot offer as high bids on the land markets. But the competition on the land market and therefore the rental prices are still higher than in the REFERENCE scenario. The reason is that biogas farms need land to provide substrates for the already existing biogas plants. In the OAL region, the number of biogas plants is quite low when the EEG 2.0 is introduced. Therefore the rental prices in the EEG 2.0 scenario are closer to the REFERENCE scenario.

Besides the rental prices, the EEG 2.0 has a strong impact on structural change when it comes to farm sizes and farm exits. Farms which invested in biogas production before the introduction of the EEG 2.0, have an even higher potential to grow faster than other farms. They benefit from the fact, that from 2014 rarely any farm invests in biogas production, but they still get the guaranteed high feed-in tariffs. Therefore the competition for them on the land market is lower than in the EEG

scenario. The model results show that indeed farms with biogas production grow in the EEG 2.0 scenario by ca. 184 % to 3320 ha on average between 2012 and 2026 while non-biogas farms increase their size on average by ca. 75 % up to ca. 483 ha on average in the Altmark. But one has to remark that there are not many biogas farms left in 2026 (cp. Fig. 10). In the OAL region biogas farms grow also faster than in the EEG scenario, but not as strong as in the Altmark. Here they increase their size by 83% up to 327 ha on average. The reason here is that farms invest in biogas production even after the introduction of the EEG 2.0. Non-biogas farms grow by about 60% up to ca. 44 ha. On reason for the difference between the EEG and EEG 2.0 scenario is a shift between biogas and non-biogas farmers. Even if biogas farms can increase their size in the EEG 2.0 scenario dramatically, the overall structural change is similar to the EEG scenario. Between 2012 and 2026 41 % of the farms close (in the Altmark around 31%). But because of less biogas farmers (86 % less in the Altmark and 79 % less in the OAL compared to the EEG scenario), non-biogas producers have better opportunities to increase their size than in the EEG scenario.

4. Conclusions

We analysed impacts of biogas production regarding the production choice of farms, the competition between farms, and impacts on agricultural structural change.

Our analyses showed that on the farm level biogas production provides especially for large and well managed farms a profitable income opportunity. Biogas farms gain a main part of revenues from this new branch. Not only revenues absolutely increase, also the composition of total revenue changes such that biogas production takes over a significant part of revenue contribution. It implies an increasing dependency of the whole farm on their biogas plant(s). Furthermore, the whole production structure of a farm changes. Our simulation results show that biogas production leads to an intensification of land use, especially to an increase in cultivation of grass silage instead of meadows, maize instead of other crops and to an increase in livestock production (cattle). The proportion of maize increases because silage is used as substrate for the biogas plant and as feed in cattle keeping. In general, biogas production provides additional incentives for livestock production because of the synergies (i.e. manure use). As result of an increased value added through biogas production and high competition among farms, rental prices increase. This may be a threat particularly for biogas farms which are smaller and have less management capabilities. On average, biogas farms do not increase their profitability, while the variance of the biogas farms' profits is significantly higher. The main reason for these effects can be seen in the fact that a significant share

of the value added is transferred via increased rental prices to the land owners. These rental prices are driven by the marginal land rents of the most efficient biogas farms.

Summing up, we conclude that biogas production provides opportunities especially for larger farms with high management capabilities. It can be a profitable option in times of increasing uncertainty and volatility of agricultural prices due to globalization and liberalisation of the EU agricultural markets. While it seems to be a safe option, one kind of uncertainty still remains in the sector because the developments in the bioenergy market are policy driven. Therefore, the market conditions and developments are affected as the demand for biogas is raised artificially through the guaranteed feed-in tariffs. Specific policy measures, such as the reduction of guaranteed prices in the EEG 2.0, should counteract to the distortion of markets and take account of rising energy prices for consumers. Part of the structural effects on the agricultural regions can be successfully reduced. However, the EEG has already strongly influenced the structure, so that some things can slowly while others cannot at all be reversed. Additionally the relatively strong reduction in guaranteed tariffs affects especially biogas producing farms. Farms that invest in biogas and change their whole production structure accordingly, can get problems when the first plants are depreciated and they had to replace them. Our results show that such replacements do not take place in the Altmark, and in OAL there are only investments in very small plants, because there is still the manure bonus granted.

Acknowledgements

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Tables and Figures

Table 1. Assumptions on biogas production from 2012 to 2026

	Altmark			OAL		
	150 kW	**450 kW**	**800 kW**	**70 kW**	**125 kW**	**200 kW**
Feed-in tariff in 1,000 Euro/year (dep. on mix)	208-213	544-579	935-992	93-118	168-173	295-303
Feed-in tariff in 1,000 Euro/year (EEG 2.0)	129*	401*	720*	55-111*	99*	161*
Investment costs in 1,000 Euro	850	1,825	265	420	625	800
Investment costs in Euro/kW	5,667	4,056	3,313	6,000	5,000	4,000
Calculated substrate costs in 1,000 Euro/year (w/o costs for manure)	66-99	198-277	351-476	35-50	59-85	93-131
working hours (dep. on mix)	894-1,064	1,344-1,581	1,839-2,227	623-642	709-738	819-862

* from 2014 in the biogas2014 scenario

Source: Own assumptions according to BMJ (2011), KTBL (2010).

Table 2. Assumptions on substrate mixtures from 2012 to 2026

	Altmark			OAL		
	Mix 1	**Mix 2**	**Mix 3**	**Mix 1**	**Mix 2**	**Mix 3**
Cattle manure	60%	30%	-	80%	50%	45%
Maize silage	20%	60%	20%	10%	50%	20%
Grass silage	20%	10%	20%	10%	-	35%
Whole-crop-silage	-	-	40%	-	-	-
Rye grain	-	-	20%	-	-	-

Source: Own assumptions according to Grundmann et al. (2006), KTBL (2010).

Table 3. Basis Payment in ct/kWh

Size	EEG	EEG 2.0
75 kW	25,00*	23,73*
150 kW	14,30	13,66
500 kW	12,30	11,78
5 MW	11,00	10,55
20 MW	6,00	

* Minimum share of manure in the substrate mixture is 80%

Source: Juris (2014)

Table 4. Characteristics of biogas and non-biogas farms in the biogas scenario 2012

Characteristics	Altmark		OAL	
	Biogas farms	Non-biogas farms	Biogas farms	Non-biogas farms
Number of farms	90	639	4	924
Average farm size in ha	1157	274	176	28
Average farm size in ESU*	190	106	77	31
Number of dairy cows	1048	55	521	90
Equity capital in EUR	389,098	246,412	695,357	354,779

* ESU means European size units, one ESU equals to 1,200 Euro standard gross margins.

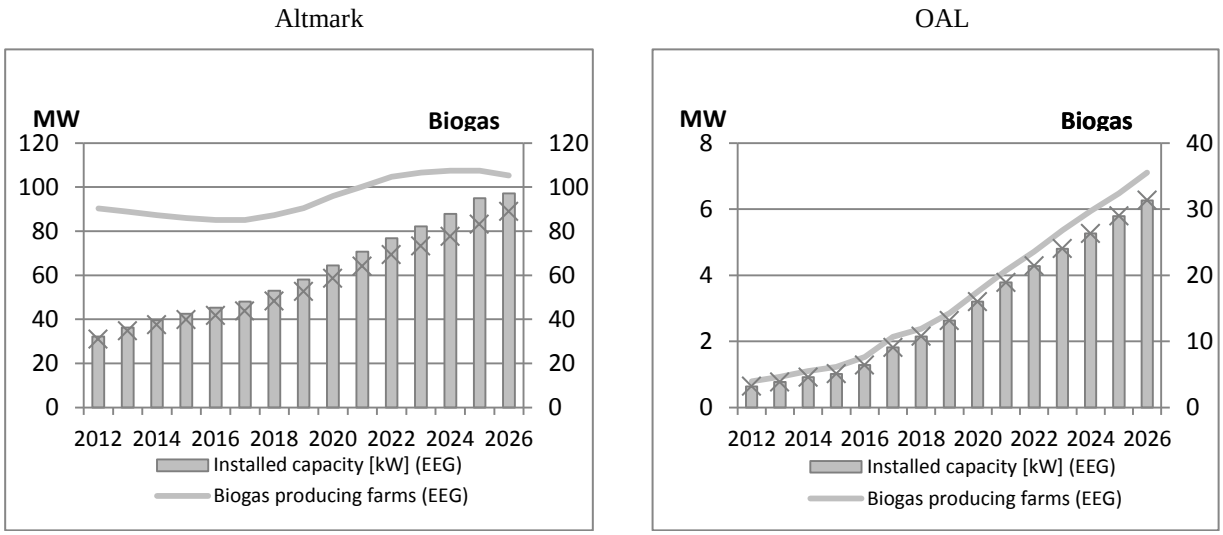
Source: Own simulation results from AgriPoliS.

Table 5. Equity share and return of equity of biogas farms in the REFERENCE and EEG scenario (model results)

	Scenario	2012	2016	2020	2024
Altmark					
Equity ratio in %	EEG	32.9	33.6	37.9	42.4
	REFERENCE	49.2	52.1	57.4	62.7
Return of equity in %	EEG	6.5	6.5	6.4	3.4
	REFERENCE	6.7	6.4	7.8	7.0
OAL					
Equity ratio in %	EEG	74.6	74.9	73.7	72.2
	REFERENCE	76.2	76.9	74.6	73.3
Return of equity in %	EEG	7.3	6.2	5.7	6.5
	REFERENCE	7.2	6.0	5.8	6.8

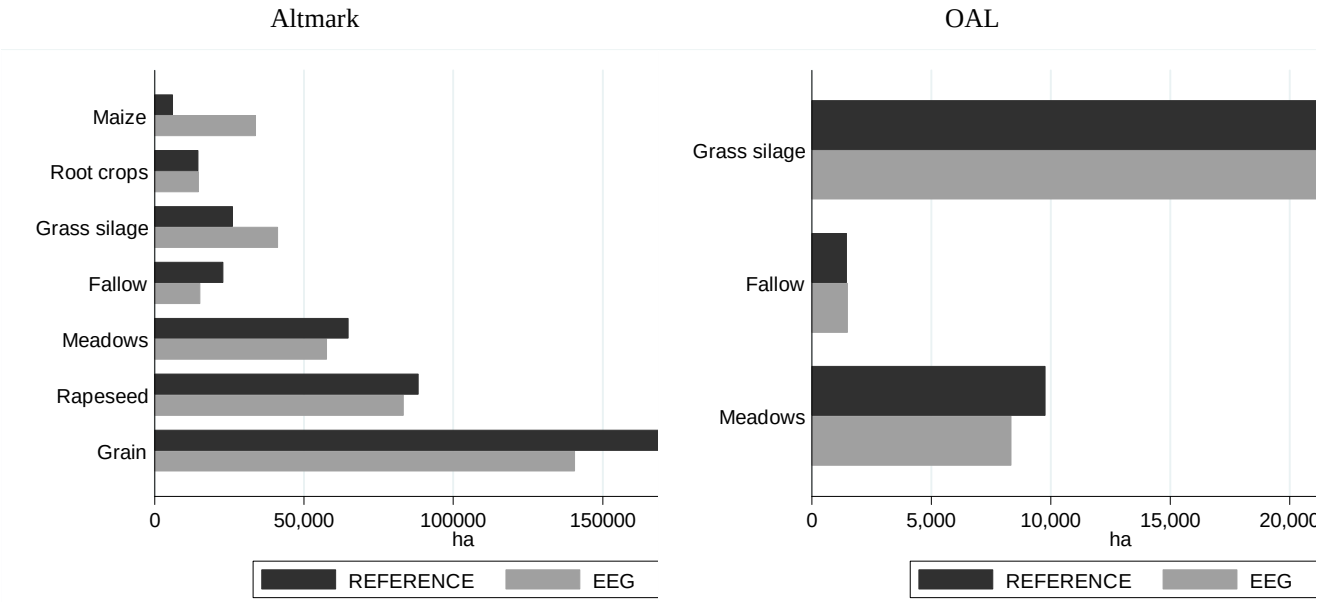
Note: Biogas farms in the REFERENCE scenario are those farms which invest in biogas plants in the EEG scenario (they do not produce biogas in the REFERENCE scenario).

Source: Own simulation results from AgriPoliS.



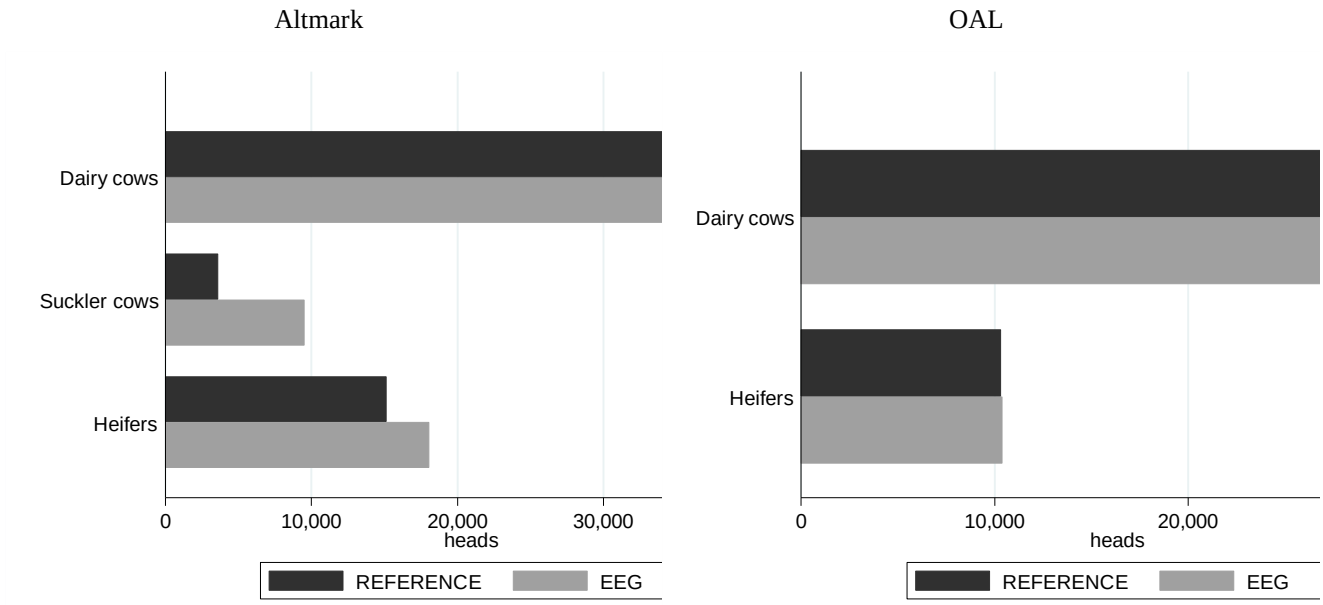
Source: Own simulation results from AgriPoliS.

Fig. 1. Number of biogas producing farms and their installed and used capacity in kilowatt in the EEG scenario, 2012-2026 (model results)



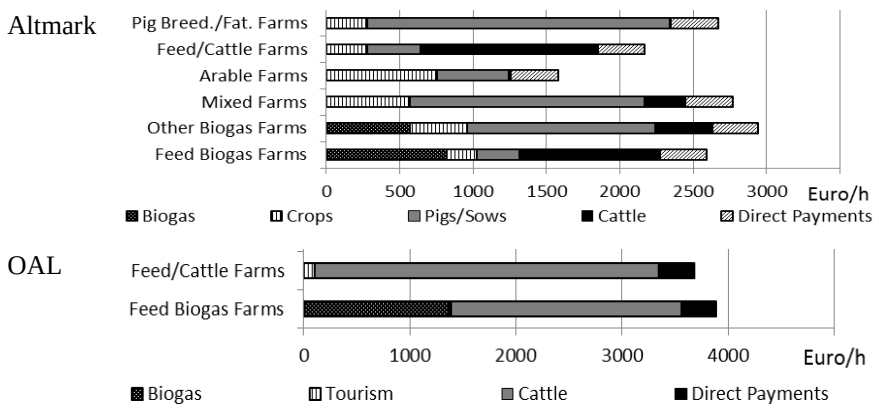
Source: Own simulation results from AgriPoliS.

Fig. 2. Cultivation size of different crop types in the REFERENCE and EEG scenario, 2020 (model results)



Source: Own simulation results from AgriPoliS.

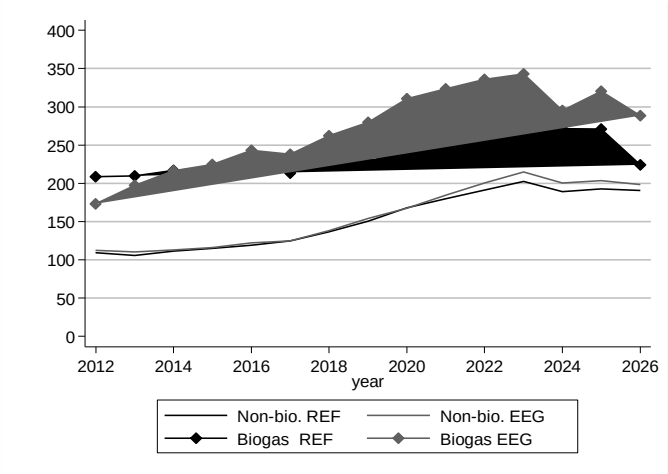
Fig. 3. Number of cows and heifers in the REFERENCE and EEG scenario, 2020 (model results)



Source: Own simulation results from AgriPoliS.

Note: Feed biogas farms are feed farms with biogas production, other biogas farms are mixed, arable or pig breeding/fattening farms with biogas production. As can be seen the other farm types do not produce biogas.

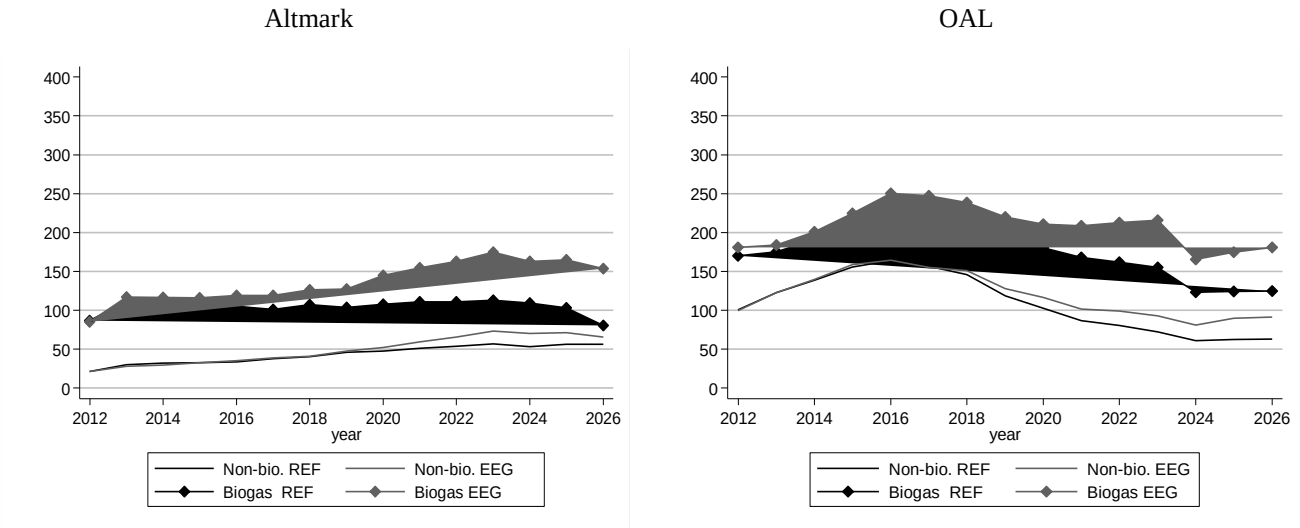
Fig. 4. Composition of revenue of different farm types in Euro per hectare in the EEG scenario, averages 2012-2026 (model results)



Note: Biogas EEG: average rental price for rented arable land of biogas farms in the EEG scenario, Biogas REF: average rental price for rented arable land of farms in the REFERENCE scenario which invest in the EEG scenario in biogas plants (they do not produce biogas in the REFERENCE scenario); same for non-biogas farms (Non-bio.) in EEG and REFERENCE scenarios.

Source: Own simulation results from AgriPoliS.

Fig. 5. Average rental prices for rented arable land in Euro per hectare of biogas and non-biogas farms in the model region Altmark between 2012 and 2026, REFERENCE and EEG scenario (model results)

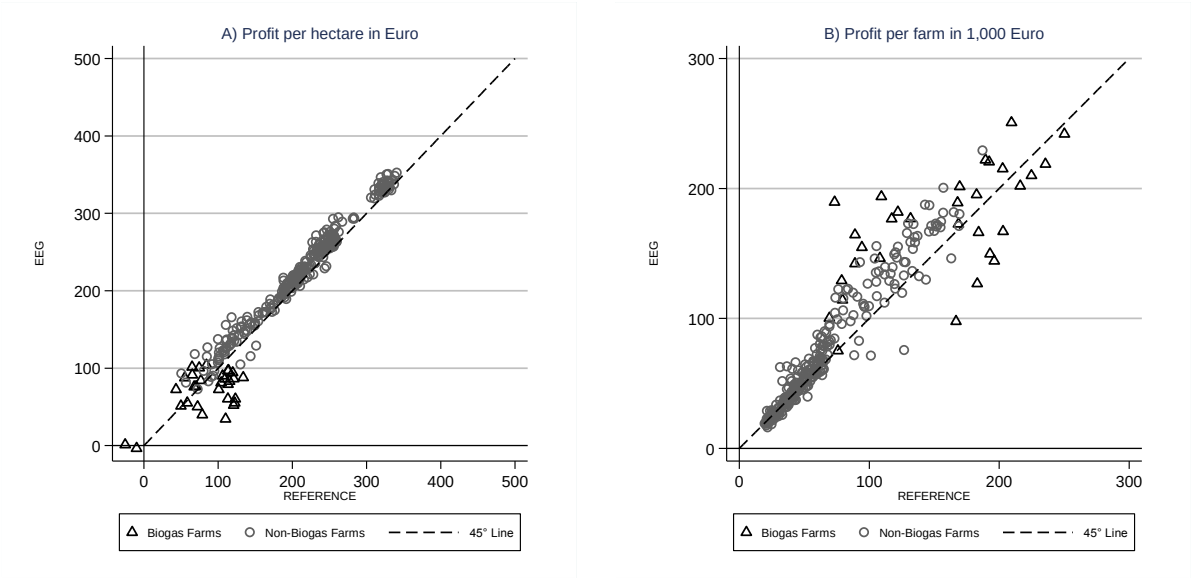


Note: Biogas EEG: average rental price for rented arable land of biogas farms in the EEG scenario, Biogas REF: average rental price for rented arable land of farms in the REFERENCE scenario which invest in the EEG scenario in biogas plants (they do not produce biogas in the REFERENCE scenario); same for non-biogas farms (Non-bio.) in EEG and REFERENCE scenarios.

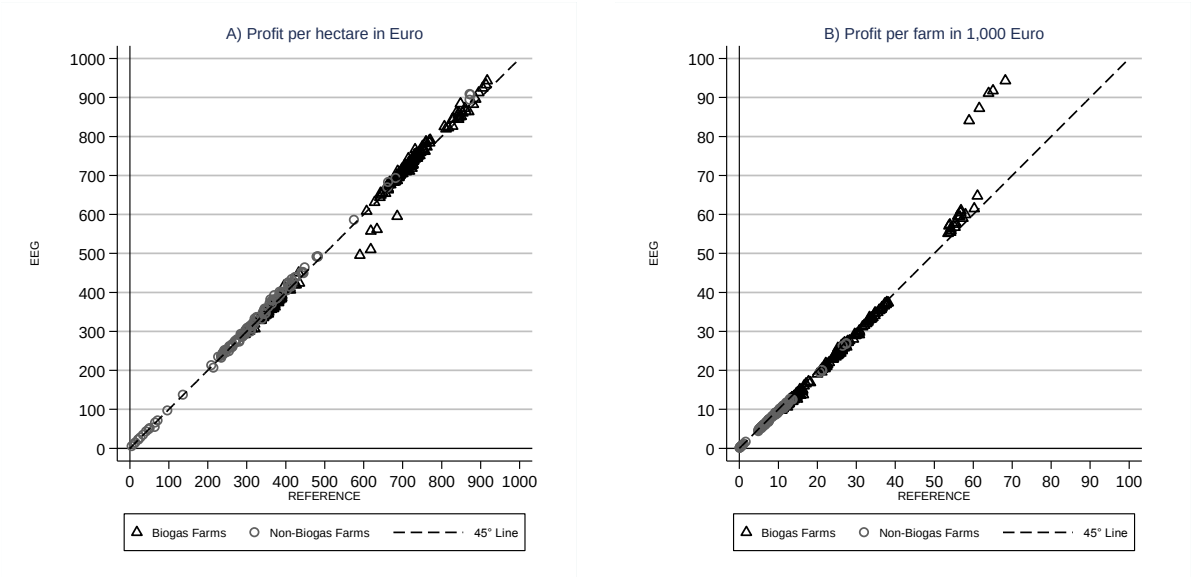
Source: Own simulation results from AgriPoliS.

Fig. 6. Average rental prices for rented grassland in Euro per hectare of biogas and non-biogas farms in the model regions Altmark and OAL between 2012 and 2026, REFERENCE and EEG scenario (model results)

Altmark



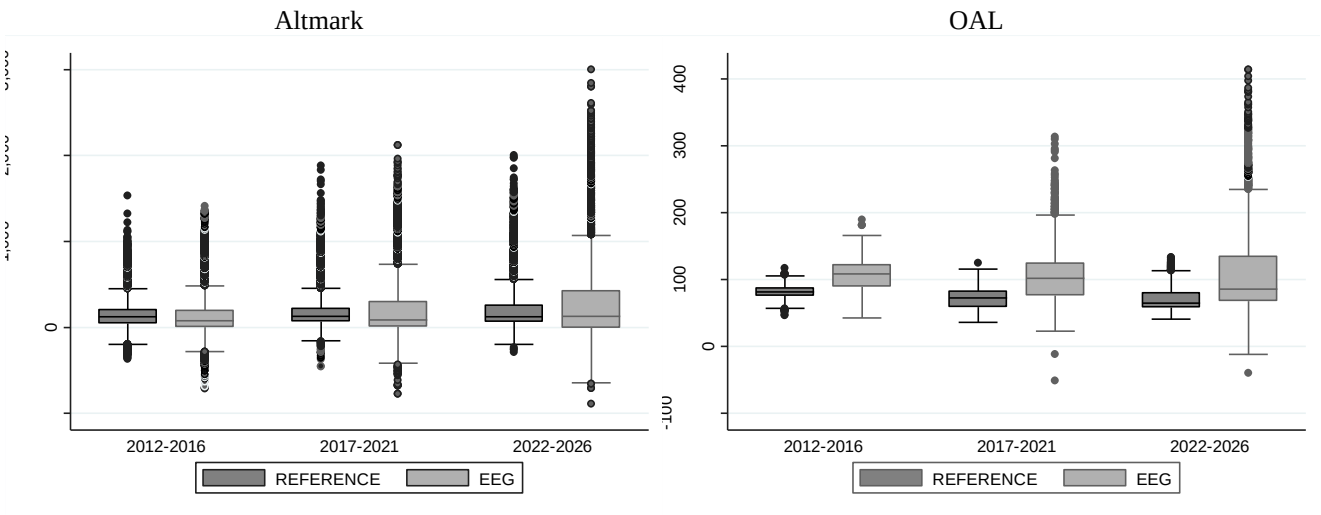
OAL



Note: A) The first scatterplot shows average profits per hectare of single biogas and non-biogas farms between 2012 and 2026(mean of 100 repetitions). Farms which are on the 45° line perform equally well in both scenarios. Farms underneath the 45° line benefit in the REFERENCE scenario, farms above the 45° line benefit in the EEG scenario. B) The second scatterplot shows the average profit per farm of single biogas and non-biogas farms between 2012 and 2026 in 1,000 Euro.

Source: Own simulation results from AgriPoliS.

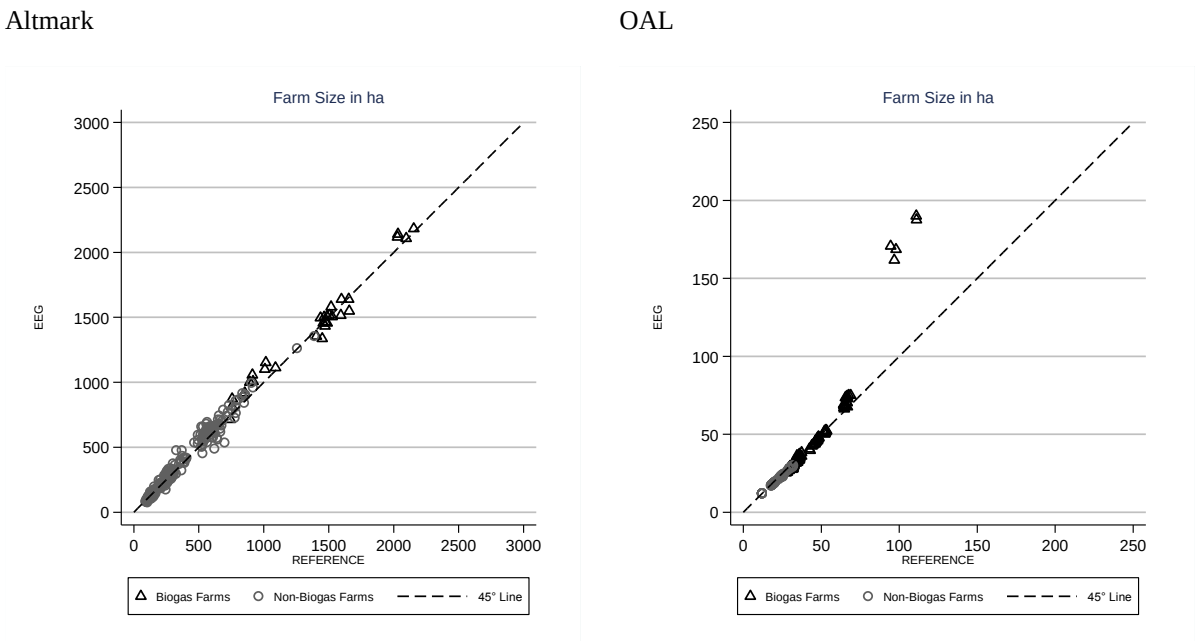
Fig. 7. Average profit A) per hectare and B) per farm of surviving farms between 2012 and 2026 in the REFERENCE and EEG scenario (model results)



Note: Only biogas farms are considered, i.e. farms which invest in farms in the EEG scenario in biogas plants (they do not produce biogas in the REFERENCE scenario).

Source: Own simulation results from AgriPoliS.

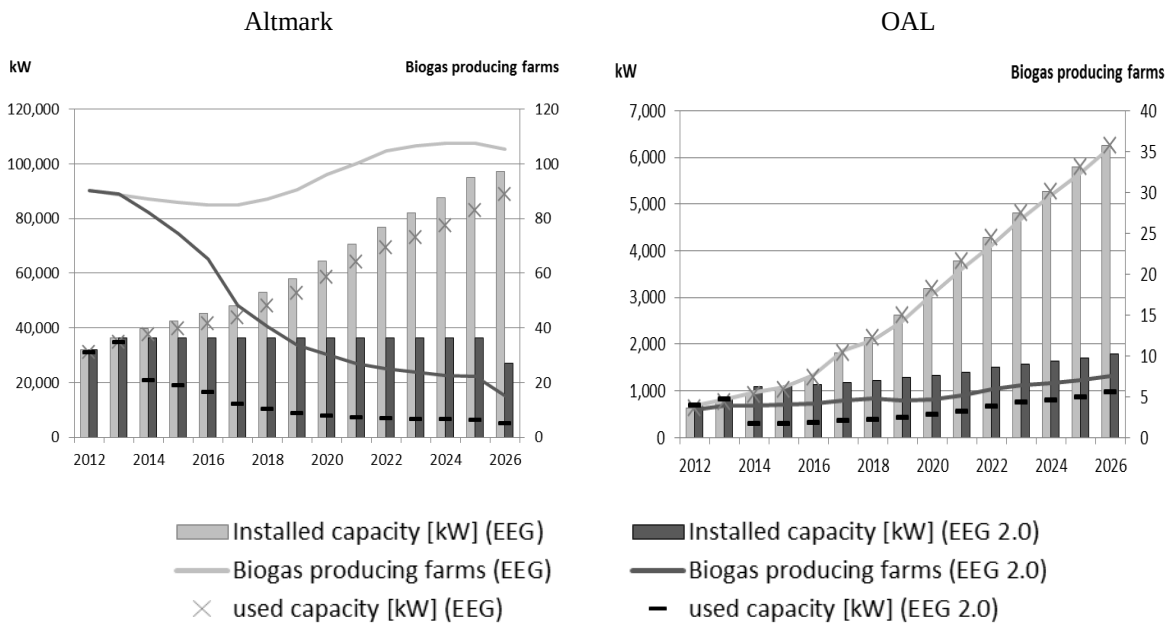
Fig. 8. Distribution of average total profits per biogas farm in 1,000 Euro in the time periods 2012-2016, 2017-2021 and 2022-2026, REFERENCE and EEG scenario (model results)



Note: Average farm size in hectare of single farms between 2012 and 2026 (mean of 100 repetitions). Farms which are on the 45° degree line have equal size in both scenarios. Farms underneath the 45° line are larger in the REFERENCE scenario, farms above the 45° line farm more hectares in the EEG scenario.

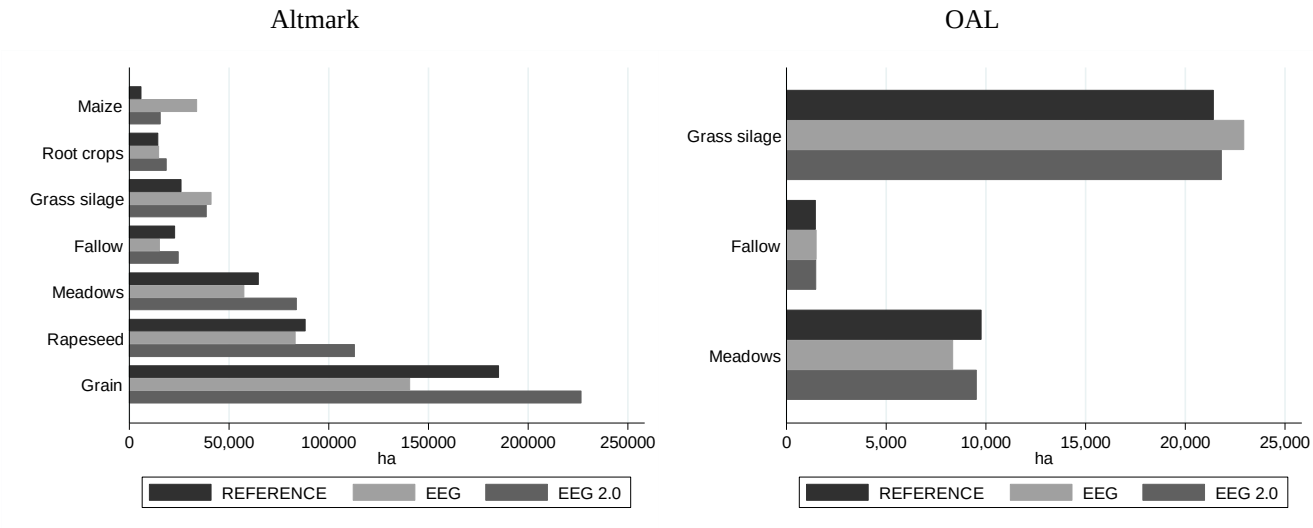
Source: Own simulation results from AgriPoliS.

Fig. 9. Average farm size of surviving biogas and non-biogas farms between 2012 and 2026 in the REFERENCE and EEG scenario (model results)



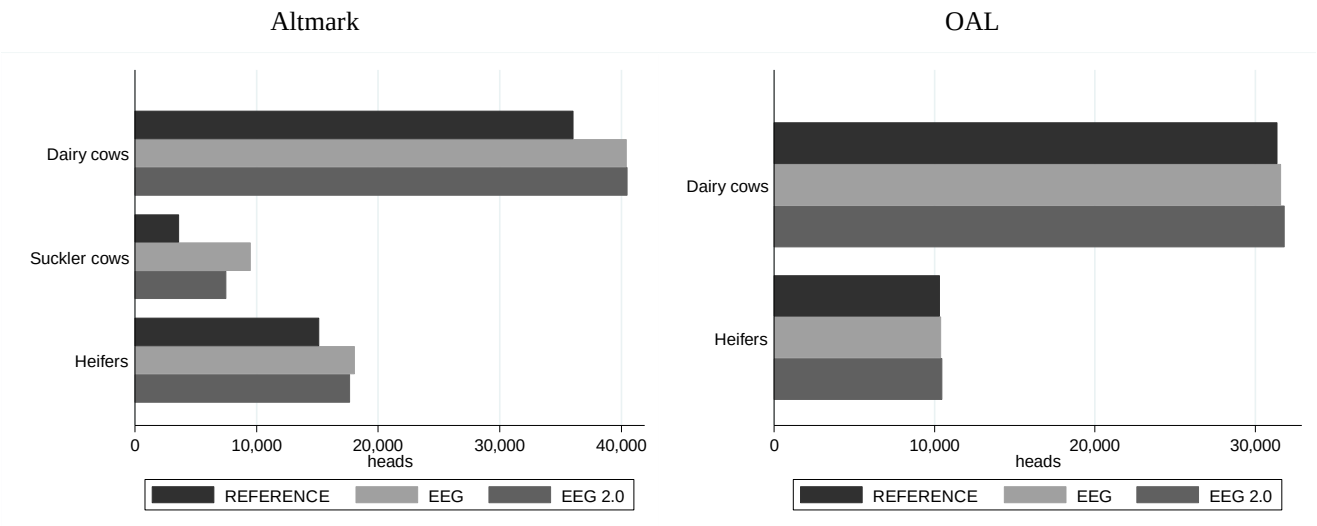
Source: Own simulation results from AgriPoliS.

Fig. 10. Number of biogas producing farms and their installed and used capacity in kilowatt in the EEG and EEG 2.0 scenario, 2012-2026 (model results)



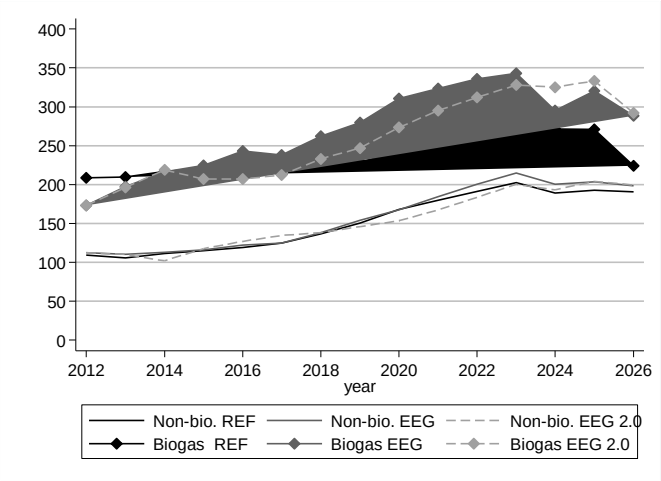
Source: Own simulation results from AgriPoliS.

Fig. 11. Cultivation size of different crop types in the REFERENCE, the EEG and EEG 2.0 scenario, 2020 (model results)



Source: Own simulation results from AgriPoliS.

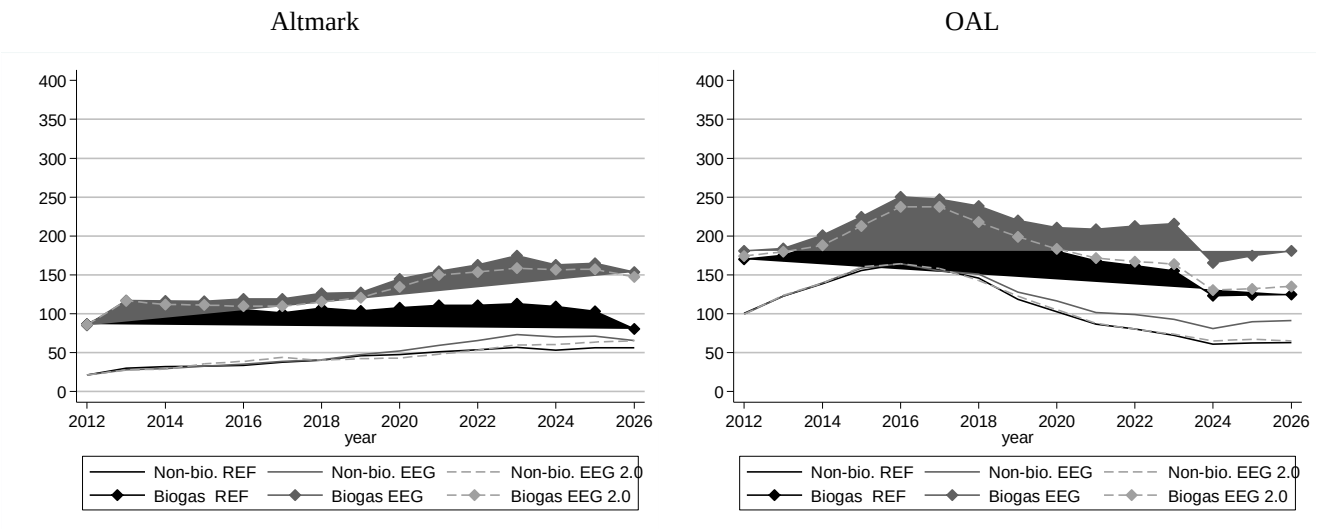
Fig. 12. Number of cows and heifers in the REFERENCE, the EEG and EEG 2.0 scenario, 2020 (model results)



Note: Biogas EEG: average rental price for rented arable land of biogas farms in the EEG scenario, Biogas REF: average rental price for rented arable land of farms in the REFERENCE scenario which invest in the EEG scenario in biogas plants (they do not produce biogas in the REFERENCE scenario); same for non-biogas farms (Non-bio.) in EEG and REFERENCE scenarios.

Source: Own simulation results from AgriPoliS.

Fig. 13. Average rental prices for rented arable land in Euro per hectare of biogas and non-biogas farms in the model region Altmark between 2012 and 2026, REFERENCE, EEG and EEG 2.0 scenario (model results)



Note: Biogas EEG: average rental price for rented arable land of biogas farms in the EEG scenario, Biogas REF: average rental price for rented arable land of farms in the REFERENCE scenario which invest in the EEG scenario in biogas plants (they do not produce biogas in the REFERENCE scenario); same for non-biogas farms (Non-bio.) in EEG and REFERENCE scenarios.

Source: Own simulation results from AgriPoliS.

Fig. 14. Average rental prices for rented grassland in Euro per hectare of biogas and non-biogas farms in the model regions Altmark and OAL between 2012 and 2026, REFERENCE, EEG and EEG 2.0 scenario (model results)

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