Energy policies and their impact on establishing nature areas in Poland: an AGE analysis

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Abstract

Current climate policies in Poland target for an increase in bioelectricity share in total electricity production. In Poland most of the renewable energy comes from biomass (around 90%). Most probably, in the future, biomass will continue to play a dominant role within the renewable energy sources. However, a usual concern is that large-scale biomass plantations might increase pressure on the productive land and might cause a substantial increase of food. The aim of this chapter is to investigate the impact of different energy policies, focused on increasing the shares of bioelectricity in the total electricity production, on land use and land cover change, and possible impacts on reestablishment of natural areas. For this purpose, we develop an applied general equilibrium model (AGE) with special attention to biomass and agricultural crops for a small open economy, with an Armington specification for international trade. In the model four land classes are distinguished to capture differences in productivity from diverse land types. The emissions of the major greenhouse gases CO_2, N_2O and CH_4 are also captured. It is unlikely that short-term Polish climate policy targets will induce a shift from agricultural to biomass production sufficiently large to achieve the government targets for bioelectricity use. The results show that Polish policy targets of increasing the bioelectricity shares can be fulfilled with modest emission reduction rate and bioelectricity subsidy levels. Moreover, we can conclude that multi-product crops can substantially increase the potential for bioelectricity. Presented climate policies, have not only a positive impact on emission reduction, but also on reestablishment of semi natural areas, especially when utilizing multi-product crops.

1. Introduction

Current climate policies in Poland target for an increase in bioelectricity share in total electricity production. Considering the fact that in Poland most of the renewable energy comes from biomass, around 90% (2002a), it is expected that, in the near future, bioelectricity from biomass will continue to play a dominant role within the renewable energy sources. To meet the demand for clean energy, once stringent climate policies take place, large scale biomass plantations are anticipated. Except for their primary function, such as providing CO_2 neutral fuels, they reduce the dependence on fossil fuels supply.

Biomass plantations can positively influence the environment. They can contribute to the improvement of soil and water quality, sequester carbon in the soil and create an environment for many species (Borjesson, 1999, Londo et al., 2005, Tolbert et al., 2002). Due to these characteristics, we claim that the biomass plantations can carry similar functions to the nature areas. That is why we call them semi-nature.

However, an often-heard concern is that large-scale biomass plantations might increase pressure on the productive land and might cause a substantial increase of food prices see for instance Azar (2003, 2001) McCarl and Schneider (2001). In contrast there are claims that current overproduction of food allows for using a part of the agricultural land for other practices, such as energy fields, see e.g. Tilman et al., (2002), Trewavas (2002) and Wolf et al., (2003).

To reduce the competition between agriculture and biomass for land and to increase biofuel supply a multi-product crops term can be used. Dornburg (2005) defines it as follows: multi-product crops can be defined as crops that can be split into two or more different parts that are used for different applications. One part of the crop is used directly as energy, i.e. it is used as solid fuel or converted to liquid fuel and the other for material applications. Introducing such systems can influence the changes in land prices and land use allocation.

Different types of models exist to study the possible land shift between agriculture and biomass or forestry and its impact on the economy and environment. There are many agricultural models that focus mainly on land shifts, without including any energy systems. Examples of such models include POLYSYS (Torre Ugarte de la and Ray, 2000) and GOAL (WRR, 1992). Walsh et al. (2003) modified the agricultural model POLYSIS to include specific biomass crops (switch grasses, poplar and willow) and provide estimates for changes in annual land use. These models are based on linear techniques. An example of a partial equilibrium model used for determining the allocation of food and biomass crops is the ASM model (McCarl et al., 1993), that accurately describes the agricultural sector in the USA. This model has few successors; one of them is FASOM that enlarges ASM to include the forestry sector (van Ierland and Lansink, 2003). Another successor is the ASMGHG model that includes emissions of greenhouse gases and mitigation possibilities (Schneider and McCarl, 2003). Different from these models our approach goes beyond agricultural and forestry sectors. In this chapter, the interactions between agricultural sectors and other sectors of the economy are included. Moreover, we include explicitly the electricity market and endogenous CO_2 permit prices.

Models that focus on the energy supply side are e.g. MARKAL MATTER (Gielen et al., 2001) and LUCEA (Johansson and Azar, 2004). MARKAL MATTER focuses on detailed descriptions of the energy system, and its biomass modules boil down to agricultural and forestry residuals and waste. LUCEA deals with competition between biomass and food crops, using a bottom up approach. It is used to determine food and energy prices in case of stringent climate policies in the USA with exogenous CO_2 emission permit prices. Both of these models focus on different energy types; however the interactions between different sectors within the entire economy and the secondary effects of policy implementations are not modeled.

There are many models that involve detailed economic analysis of energy sector, and are able to provide the secondary effects of shifting the energy production, however, they often omit biomass resources e.g. Kumbaroglu (2003) McFarland et al., (2004), Babiker (2005) or agricultural multi-product sources e.g. Breuss and Steininger (1998), and Ignaciuk et al., (2005).

The aim of this chapter is to investigate the impact of different climate policies, focused on increasing the shares of bioelectricity in total electricity production, on land use and land cover change, and possible impacts on reestablishment of natural areas. In this context, we analyze how these policies might affect production of agricultural commodities and prices of land and electricity. Moreover, we analyze to what extent using the by-product of agriculture and forestry sectors increase the bioelectricity shares and reduces the pressure on agricultural land.

To attain our objective, we develop an applied general equilibrium model (AGE) with special attention to biomass and agricultural crops and different energy systems for a small open economy, with an Armington specification for international trade. Moreover, it distinguishes different land classes to capture differences in productivity. The emissions of the major greenhouse gases CO_2, N_2O and CH_4 are also captured.

This chapter is structured as follows. Section 2 presents the model specification. Section 3 describes the data and Section 4 provides the description of scenarios. In the following section, Section 5, the results are presented and discussed. To the end in Section 6 the conclusions are gathered.

2. Model specification

Using a CGE-framework allows us to account fully for the interlinkages between different sectors of the economy. These are relevant, as the agricultural and energy sectors have strong links with the rest of the economy. Moreover, the indirect impacts of environmental policies, those are often ignored but can be highly relevant (Dellink, 2005), are incorporated, ensuring a consistent assessment of the economic costs of environmental policy.

The model describes the entire economy, with explicit detail in the representation of production of traditional agricultural and biomass crops[1]. As in any standard general equilibrium model (CGE) all markets clear, which means that supply equals demand for all goods through adjusting relative prices (Ginsburgh and Keyzer, 1997).

In the model, 35 sectors are distinguished. We consider explicitly both agricultural and biomass sectors. The electricity sector is divided into conventional electricity and bioelectricity, depending on the fuel used for the production. We include three primary production factors: labor, capital and land. Four land classes that correspond to the six land classes used in the Polish land classification system (GUS, 2002a), are identified to capture differences in productivity from different land types. Agricultural and biomass crops can grow on three different land use classes *z1*(very good), *z2*(good), and *z3*(poor). Forestry can only grow on the *z4* type of land.

A *representative consumer* maximizes utility under the condition that expenditures on consumption goods do not exceed her income. Utility is represented by a nested constant elasticity of substitution (CES) function[2]:

$$U = CES\left(C_i, EL^N; \sigma^U\right) \qquad (1)$$

in which U is utility, C_i is the consumption of commodities from sector i and $EL^N = CES\left(C_e, C_{be}; \sigma^{EL}\right)$ where C_e and C_{be} are consumption of Electricity and Bioelectricity respectively. Parameters σ^U and σ^{EL} are substitution elasticities. Such specification allows for

[1] It is an extended version of the model described in Ignaciuk et al. (2005).

[2] The CES function $Y_i = \left(\alpha_1 X_1^\rho + \alpha_2 X_2^\rho\right)^{1/\rho}$ with $\rho = (\sigma\text{-}1)/\sigma$ is written as $Y_i = CES(X_1,X_2;\sigma)$.

substitution possibilities between different consumption goods, such as between conventional electricity and bioelectricity. Consumers own production factors and consume produced goods. Labor supply is fixed. The wage rate is fully flexible. The total availability of labor is determined by the initial endowments of the representative consumer.

Producers maximize profits subject to the available production technologies. Following Rutherford and Paltsev (2000), production technologies are represented by nested CES functions. Production functions of different commodities have a six-level nesting structure.

For production of most commodities emission permits are required. Emissions included in this model cover most of the greenhouse gases; CO_2, N_2O and CH_4. Both CH_4 and N_2O emissions are expressed in CO_2 equivalents. Data on emissions is obtained from Sadowski (2001). As CO_2 emissions come mostly from fossil fuel combustion they enter the production function in a different place as NH_4 and N_2O emissions (Figure 1). Environmental policy is implemented by reducing the number of emission permits the government auctions. This way of modeling environmental policy ensures that a cost-effective allocation is achieved (Dellink, 2005).

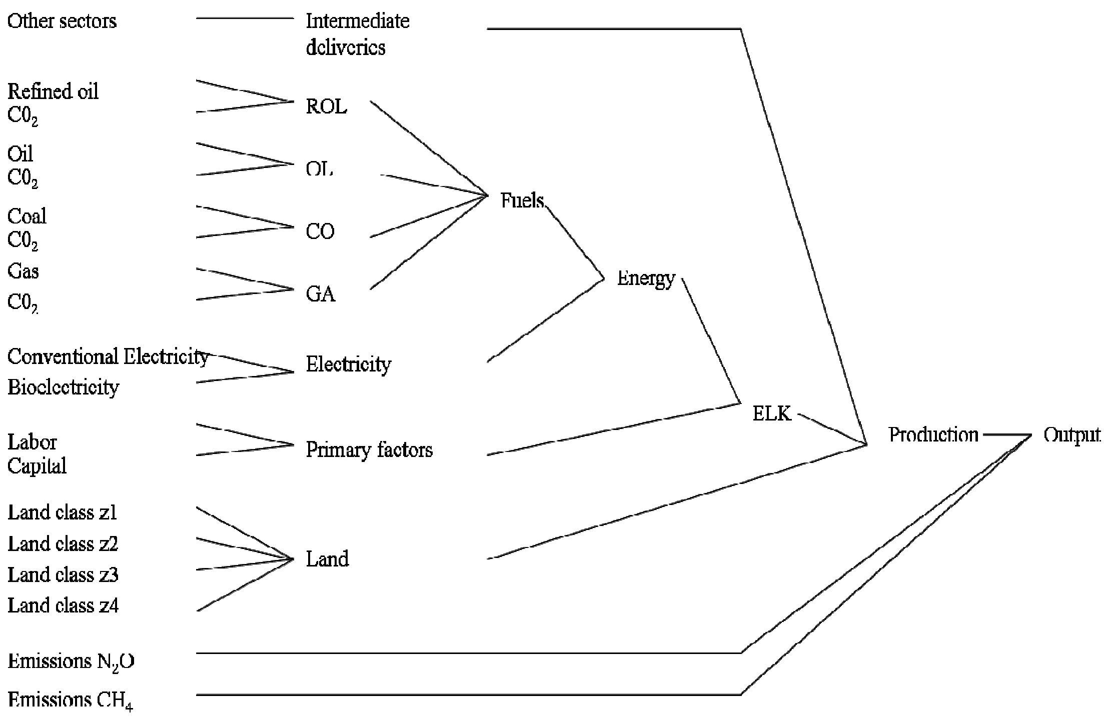

Figure 1 Nested CES function

In the model, Poland is considered to be a small open economy. It means that neither domestic prices nor traded quantities change the 'world market prices'. The international market is assumed to be large enough to absorb any quantities of goods produced in Poland and it can satisfy Polish import demands. In this model, we choose the Armington specification for traded goods, assuming that domestic and foreign goods are imperfect substitutes (Armington, 1969).

All taxes are collected by the government that uses them to finance public consumption and pay lump-sum transfers to private households. The EU subsidy is an exception and it is paid from external sources, namely EU. There are different subsidy schemes, depending on the land cover. The traditional agriculture and biomass sectors are directly subsidized, however the Forestry sector receives subsidy once it turns the agricultural land for forestry production.

In the model, the bioelectricity can be produced using the primary agricultural and biomass products as fuels or using the by-products that are produced in the conventional methods of production. Such by-products are for instance straw produced by cereals sectors or forestry residuals produced by Forestry sector. These by-products in the benchmark have low price, reflecting low demand for biofuels in benchmark. In the model, the substitution elasticity between traditional biofuels and the fuels that are produced as by-products is very high.

3. Data

To determine the benchmark equilibrium, a Social Accounting Matrix (SAM) for Poland is specified. For this purpose, we adopted the most recent available GTAP data (for 1997) (Dimaranan and McDougall, 2002). In the SAM, agricultural and biomass data are disaggregated based on the FEPFARM model built by Mueller (1995), using FAO country land use data for Poland. The FEBFARM model provides the shares of production costs. Data on land use pattern and emissions are obtained from Polish statistics (GUS, 2002a, 2002b). Data on agricultural and biomass residuals are taken from Gradziuk (2001) and Dornburg et al., (2005).

We specify the substitution elasticities between different production inputs in the production functions, based on literature surveys and experts' opinions. Estimates of substitution elasticities between capital, labor and energy, are estimated by Kemfert (1998), Rutherford and Paltsev (2000), Kiuila (2000), and Dellink (2005)[3].

4. Scenarios

Polish policy makers set two goals concerning an increase of the bioelectricity share into total electricity production: 7.5% by 2010 and 14% by 2020. We present two policy scenarios aimed to increase the bioelectricity share and to reduce CO_2 emissions. Both of these scenarios are analyzed in a unilateral setting.

Table 1 **Definition of scenarios**

Single product Setting	***Multi-product Setting***
Emission permit reduction + subsidy on bioelectricity + EU subsidies **(S)**	Emission permit reduction + subsidy on bioelectricity + EU subsidies **(M)**

The first scenario, Scenario S, considers the reduction of emission permits by 10% and adoption of bioelectricity subsidy in a single product setting. Since Poland has already fulfilled its Kyoto obligations, further emission reductions can be beneficial once Poland can trade its emission rights. Scenario M adopts the same rate of emission permits reduction (10%). However, the analysis focus on the multi-product setting. Since we analyze the impact of these scenarios in a unilateral setting it is assumed that only Poland undertakes those climate policies. An overview of the scenarios is given in Table 1.

5. Results and discussion

This section presents the results of the policy analysis for all scenarios. In section 5.1, we discuss the general results, including the impact of the scenarios on bioelectricity share, utility and prices of emission permits. Sections 5.2 and 5.3 focus on policies impact on production and land allocation, respectively. Subsection 5.4, analyses the changes in prices of different commodities, and the last subsection focuses on land use patterns.

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[3] The full data set used in the model can be obtained from authors.

5.1. GENERAL RESULTS

Figure 2 presents the influence of the implementation of CO_2 emission permit reduction combined with a biomass subsidy scheme on the share of bioelectricity in electricity production in a unilateral setting. The results show clear differences between the bioelectricity shares for the single product and the multi-product settings. Noticeably, for every level of bioelectricity subsidy, in the multi-product setting there are higher shares of bioelectricity than in the single product setting. This does not come as a surprise, considering the fact that in multi-product setting bioelectricity producers obtain cheaper biofuels.

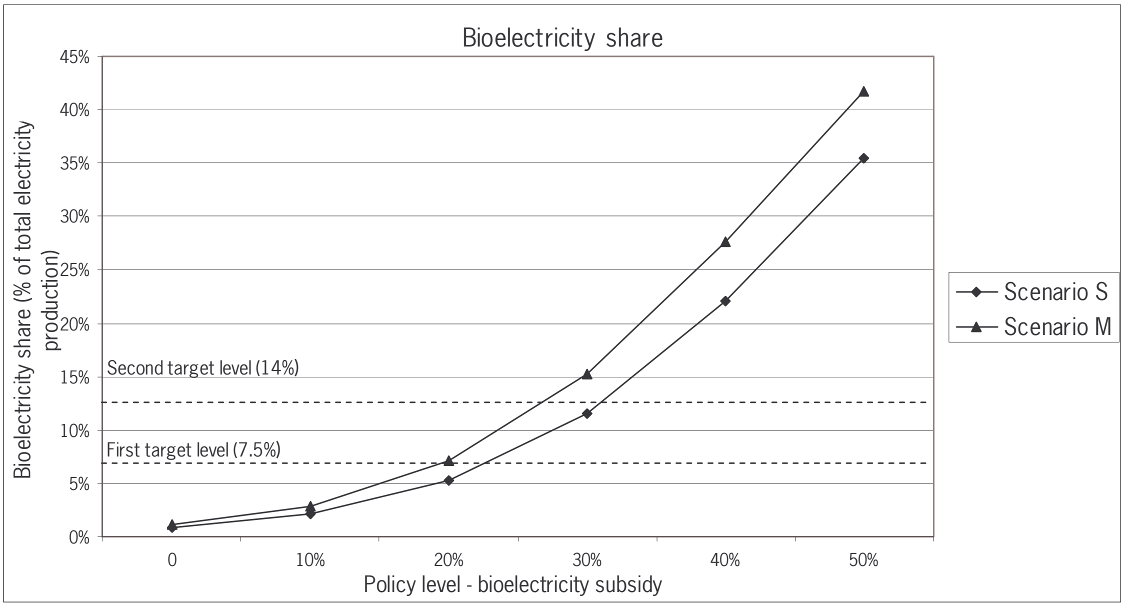

Figure 2 Biolectricity share for single product (S) and multi-product (M) scenarios for different levels of bioelectricity subsidy

First policy goal of 7.5% bioelectricity share using the single product options is reached with around 22% subsidy on bioelectricity. The same goal with the single product setting is reached with around 20% subsidy. The second goal of 14% shares is reached with around 31% subsidy rate in single product setting and by utilizing by product the same goal can be reached with around 4% less subsidies. Welfare costs of these policies tend to be virtually the same (see Figure 3). However, it may seem puzzling that the utility level increases with the size of the subsidy rate. One explanation of this is that in a second best world, bioelectricity subsidy covers some of the welfare loses that the society pays once the emission are reduced by 10%.

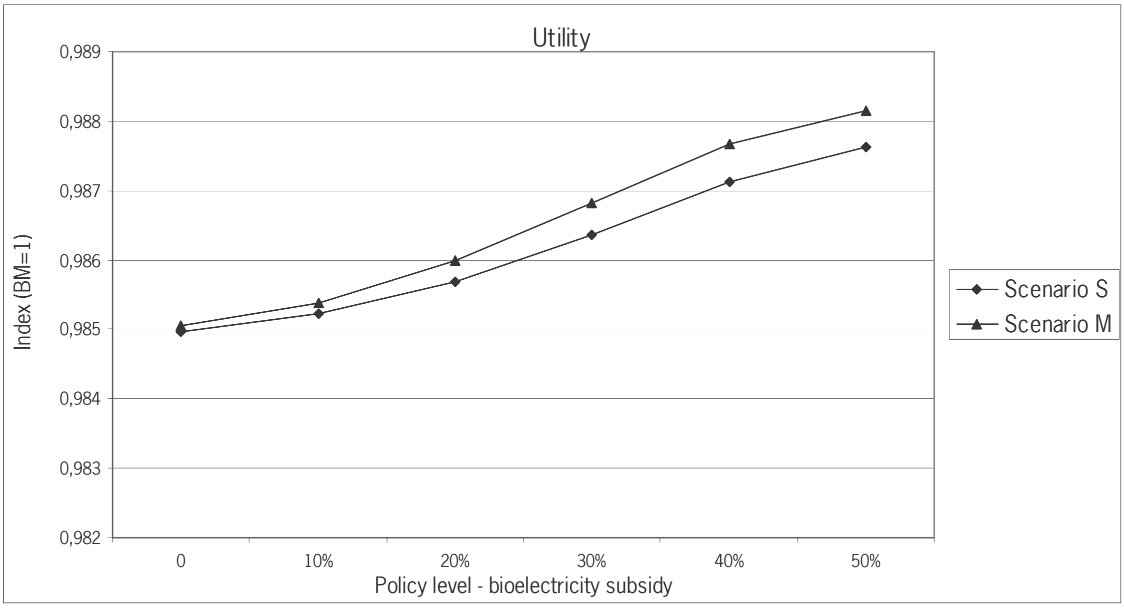

Figure 3 Utility change for single product (S) and multi-product (M) scenarios for different levels of bioelectricity subsidy

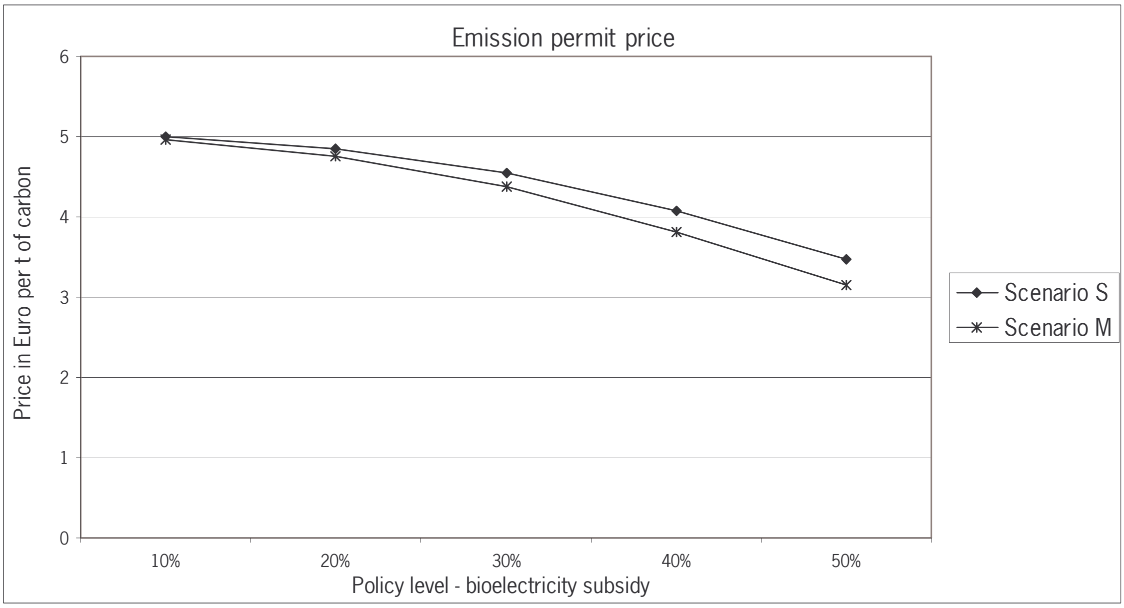

Figure 4 Emission permit price for single product (S) and multi-product (M) scenarios for different levels of bioelectricity subsidy

This phenomenon can be also explained by the fact that subsidizing bioelectricity, provides more ‘clean’ energy that can substitute the dirty conventional one. Producers and consumers can switch their demand towards CO_2 neutral fuels and reduce the demand for emission permits.

From Figures 2-4 we observe that the share of the bioelectricity, utility and price levels change in a non-linear manner. Small changes in emission reduction triggers small changes in bioelectricity shares, utility level and price of emission permits. More stringent environmental policies will affect bioelectricity shares, utility level and price of emission permits substantially more.

5.2. PRODUCTION

Table 2 comprises the results of production changes for two scenarios and for two different bioelectricity subsidy levels: 10% and 40%. The economy adapts to these reductions by switching towards (i) 'clean' energy and (ii) 'clean' production. In both scenarios there is a clear increase in bioelectricity production, considering 10% emission permit reduction and a 10% subsidy, it increases by 198% in Scenario S and 305% in Scenario M. Since the Bioelectricity sector is very small compared to Electricity one, to meet the demand of the total economy considering energy, this sector has to grow considerably. Labor and capital released from declining Electricity sector are used to intensify the production of the Bioelectricity sector. The 'clean' sectors such as e.g. sectors producing rape, willow or hemp increase their production substantially, since there is a high demand for biofuels. In multi-product setting scenario, those changes are larger than in single product setting. This difference is caused by the ability of producing more biofuels per unit of production in multilateral setting. Moreover, since the by-products are cheap, the Bioelectricity sector demands them in large quantities. Using these new fuels it can grow and substitute even more conventional electricity. Some agricultural sectors decrease their production; however it is a very small reduction, the largest changes are the three percent decline of Other Agriculture sector, with 10% biomass subsidy level.

It might seems surprising that most of the agricultural, biomass and forestry goods increase their production. This can be explained, however, by the fact that those sectors can intensify their production by substituting land for other production factors that become available due to the production losses in the industrial, energy and services sectors. In both scenarios (S and M) the dirty sectors decrease their production substantially (see Table 2). In the multi-product setting, there are slightly smaller losses in production of the 'dirty' sectors. This can be explained by the fact that using by-products, most of the agricultural and biomass sectors increases its production without internalizing additional production factors.

Table 2 Changes in the production in selected sectors for all scenarios at 10% and 40% biolelectricity subsidy rate (% change compared to benchmark)

	Single product 10%	Multi-product 10%	Single product 40%	Multi-product 40%
Other Agriculture	-3	-3	2	3
Rape	5	7	95	120
Willow	220	310	3730	4578
Hemp	17	24	299	381
Wheat	-2	-2	-1	-1
Other Cereals	-1	-1	12	16
Food & animals	-2	-2	-1	-1
Forestry	0	0	13	16
Coal	-9	-9	-9	-10
Oil	-17	-17	-16	-15
Gas	-14	-14	-14	-14
Petrochemicals	-15	-15	-14	-13
Electricity	-6	-7	-20	-23
Bioelectricity	198	305	3214	4160
Industry	-1	-1	-1	-1
Services	-1	-1	-1	-1

5.3. PRICES

The policies adopted in the model induce price changes; the AGE framework allows an analysis of relative prices, but the absolute price level is undetermined (this is solved by choosing the Consumer Price Index as numéraire). Generally, the prices of dirty goods e.g. conventional electricity, for which the production costs increase substantially given that they have to pay for emission permits, go up compared to prices of clean goods. The impact of the emission reduction policies on price level for a selection of goods is presented in Table 3. We can observe an increase of agricultural commodity prices. However, this increase is much lower than in other studies, at most 9%, if the emission permit price rises to around 40 Euro per ton of carbon. For instance Azar and Berndes (2000) conclude that with stringent environmental policies the prices of wheat can double, and McCarl and Schneider (2001) expect more than a doubling of prices for all agricultural goods if the price of emission permits would rise to 500 $ per metric ton of carbon equivalent.

Table 3 Changes in prices of selected commodities for all scenarios at 10% and 40% biolelectricity subsidy rate

	Single product 10%	Multi-product 10%	Single product 40%	Multi-product 40%
Other Agriculture	2%	2%	1%	1%
Rape	0%	0%	0%	0%
Willow	-1%	-1%	-1%	-2%
Hemp	0%	0%	0%	0%
Wheat	0%	0%	0%	0%
Other Cereals	1%	1%	1%	1%
Forestry	0%	0%	2%	2%
Electricity	3%	3%	3%	3%
Bioelectricity	-9%	-12%	-29%	-31%

Generally, the price level of land increase for all type of land (Table 4). Such increase is caused by two factors. First, the EU subsidies cause a distortion and increase the income of farmers without increasing the productivity of land. Second, in the multi-product setting, the productivity of land increases without compromising any other factors. More stringent policies, induce higher land prices.

Table 4 Changes in prices of land for all scenarios at 10% and 40% biolelectricity subsidy rate

	Single product 20%	Multi-product 20%	Single product 40%	Multi-product 40%
Land type z1	-4%	-5%	69%	91%
Land type z2	4%	6%	38%	52%
Land type z3	1%	3%	40%	55%
Land type z4	18%	31%	154%	181%

5.4. LAND USE

Table 5 presents the land use allocation of all crops. In the single product scenario there is limited land reallocation, the multi-product scenario show larger changes in sown area.

In Table 5, we can observe that the acreage of biomass (including willow, hemp and forestry) hardly increase in Scenario S for 10% emission reduction and 10% bioelectricity subsidy rate; however for 40% subsidy rate, it increases considerably to the amount of 380 000 ha.

Table 5 **Land use (in 1000 ha) for all scenarios at 10% and 40% biolelectricity subsidy rate**

		BM	Single product 10%	Multi-product 10%	Single product 40%	Multi-product 40%
Other Agriculture	z1	102,4	102,4	100,2	86,4	83,7
	z2	1839,5	1838,7	1772,9	1590,1	1550,6
	z3	1051,6	1051,2	1019,9	912,3	886,8
Rape	z1	0,0	0,0	0,0	0,0	0,0
	z2	349,4	349,6	458,5	701,1	727,7
	z3	87,3	87,3	115,3	175,8	181,9
Willow	z1	0,0	0,0	0,0	0,0	0,0
	z2	0,0	0,0	0,0	0,0	0,0
	z3	0,5	0,5	8,2	26,6	30,7
Hemp	z1	0,0	0,0	0,0	0,0	0,0
	z2	0,0	0,0	0,0	0,0	0,0
	z3	0,1	0,1	0,3	0,6	0,6
Wheat	z1	87,4	87,4	84,6	73,4	70,7
	z2	1570,1	1570,3	1497,8	1350,8	1309,1
	z3	897,7	897,8	861,6	775,0	748,7
Other Cereals	z1	218,6	218,6	223,6	213,4	210,4
	z2	3894,5	3894,9	3924,3	3895,2	3865,3
	z3	2301,1	2301,3	2333,1	2309,5	2284,7
Forestry	z4	8769,0	8769,0	8769,0	9129,2	9285,0

In Scenario M, we observe immediate change in the size of semi natural area. For 10% emission reduction and 10% bioelectricity subsidy rate it increases by 1 700 ha and for 40% subsidy rate by 540 000 ha. This large increase is caused mainly by converting some of the agricultural land into forestry, thanks to EU subsidy and the fact that Forestry sector produces also a cheap by product used as fuel in bioelectricity. This increase in acreage of semi natural areas is caused mainly by increased demand for clean fuels. Hence, the proposed policies target the reduction in CO_2 emission as well as increase of nature areas.

6. Conclusions

In this chapter we present a general equilibrium model to investigate the effects of climate policies on biomass systems and their influence on economy and the resulting land reallocation.

Based on our analysis, we would like to highlight some interesting results. It is unlikely that short-term Polish climate policy targets will induce a shift from agricultural to biomass production sufficiently large to achieve the government targets for bioelectricity use. The results show that Polish policy targets of increasing the bioelectricity shares can be fulfilled with modest emission reduction rates and bioelectricity subsidy levels. Moreover, we can conclude that multi-product crops can substantially increase the potential for bioelectricity and at the same time reduce the pressure on productive land.

With stringent policies most of the agricultural, biomass and forestry commodities increase their production. There are several explanatory factors of this phenomenon. First, those sectors can intensify their production by substituting land for other production factors that become available due to the production losses in the industrial, energy and services sectors. Second, due to EU subsidies, production of land intensive sectors becomes more profitable. Moreover, using multi-products crops brings additional benefits to many agricultural and biomass sectors, they can benefit from having higher output per unit of production factors.

Climate policies, that were discussed, have not only a positive impact on emission reduction, but also on reestablishment of semi-natural areas. The positive externalities of these climate policies are visible in reclaiming productive land for “nature’. Especially when using multi-product crops, we observe an increase of acreages of biomass and forestry plantations.

At current prices, bioelectricity is not economically interesting. The benefits that are brought by multi-product crops are the reduced prices of bio fuels itself and of bioelectricity. Thus, the costs of climate policy can be substantially reduced and the policy goals set for bioelectricity use can be achieved with less effort. However to reap all these opportunities, stringent environmental policies are needed.

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