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Mutual Dependence between Sustainable Energy- and Sustainable Agriculture Policies-from the Global and European Perspective

Abstract

The aim of the paper is to present the interrelationship between the sustainable energy, especially renewable energy sector and sustainable agriculture policy from both: the European and the global perspectives.

In the world and European economy the role of Renewable Energy Technologies is still increasing. Energy efficiency; sustainable agriculture; renewable energies for rural development belong to main poles of sustainable development in the world economy and its regions.

Agriculture is one of the economic sectors to which the EU commitment to reduce emissions of greenhouse gases applies. Like any other economic sector, agriculture produces greenhouse gases and is a major source of the non-CO_2 greenhouse gases methane and nitrous oxide. It is also the strong relationship between the sustainable agriculture sector and the renewable energy development possibilities. The sustainable agriculture can be seen as a source of renewable energy.

1. Introduction

The current financial and economic crisis should not delay cost-effective investments or programmed energy projects that would create jobs, enhance energy security and help limit greenhouse gas emissions in the short and medium term. Innovation and knowledge are key factors for supporting the

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recovery and putting the world economy on a more sustainable growth path. It is needed to accelerate innovation in relation to long-term challenges and to encourage the development of new industries, companies and services that will be decisive to create new sources of growth. The interlinked challenges of climate change, energy security and the sustainable and efficient use of natural resources are amongst the most important issues to be tackled in the strategic perspective of ensuring global sustainability. A shift towards green growth will provide an important contribution to the economic and financial crisis recovery.

Stable and secure energy availability is indispensable for social and economic development; it is essential to ensure global energy security and energy access in developing countries. The emergency response to the economic crisis should not overlook the opportunity to facilitate a global green recovery putting our economies on a path towards more sustainable and resilient growth. Our fiscal stimulus packages are increasingly investing in measures encouraging the creation of green jobs and low-carbon, energy efficient and sustainable growth. These include energy efficiency measures, investment in public transportation infrastructure, incentives for recycling and for fuel-efficient vehicles, research in alternative sources of energy, support for renewable energy technologies, as well as in enhanced CO2 reduction.

The emergency response to the recent economic crisis should not overlook the opportunity to facilitate a global green recovery putting our economies on a path towards more sustainable and resilient growth. Our fiscal stimulus packages are increasingly investing in measures encouraging the creation of green jobs and low-carbon, energy efficient and sustainable growth. These include energy efficiency measures, investment in public transportation infrastructure, incentives for fuel-efficient vehicles, research in alternative sources of energy, support for renewable energy technologies, as well as in enhanced CO2 reduction. Energy is central to our lives. We rely on it for transport, for heating and cooling our homes, and running our factories, farms and offices. However, fossil fuel is a finite resource and is a major cause of global warming. So we can no longer take energy from fossil fuels for granted. We must create an integrated energy and environment policy based on clear targets and timetables for moving to a low-carbon economy and saving energy. Driving the policy is the EU's bid to achieve a 20% reduction in its greenhouse gas emissions by 2020 (compared with 1990 levels), mainly by boosting the use of renewable energy and curbing energy consumption. The measures will also reduce dependence on imports of gas and oil and help shelter the economy from volatile energy prices and uncertain supplies.

The EU policy focuses on creating a competitive internal energy market offering quality service at low prices, on developing renewable energy sources, on reducing dependence on imported fuels, and on doing more with a lower consumption of energy.

2. Sustainable energy- strategy and policy issues

The Green Paper A European Strategy for Sustainable, Competitive and Secure Energy [1]was an important milestone in developing an energy policy for the European Union (EU). If Europe is to achieve its economic, social and environmental objectives, it has to address major energy-related issues such as a growing dependence on energy imports, volatile oil and gas prices, climate change, increasing demand, and obstacles to a fully competitive internal energy market. The EU must exploit its position as the world's second largest energy market and as world leader in demand management and the promotion of renewable energy sources[2].

The diagnose concerning the situation in the European energy sector was based on the most important factors of the following evidence:

- A need for investments to meet expected energy demand and to replace ageing infrastructure.
- The European import dependency is rising. Unless we can make domestic energy more competitive, in the next 20 to 30 years around 70 % of the Union's energy requirements, compared to 50% today, will be met by imported products – some from regions threatened by insecurity.
- Reserves are concentrated in a few countries. Today, roughly half of the EU's gas consumption comes from only three countries (Russia, Norway, Algeria). On current trends, gas imports would increase to 80 % over the next 25 years. The EU currently imports 82% of its oil and 57% of its gas making it the world's leading importer of these fuels.
- Global demand for energy is increasing. World energy demand – and CO2 emissions – is expected to rise by some 60% by 2030. Global

[1] GREEN PAPER, A European Strategy for Sustainable, Competitive and Secure Energy, Brussels, 8.3.2006; COM(2006) 105 final.

[2] http://europa.eu/legislation_summaries/energy/european_energy_policy/l27062_en.htm

oilconsumption has increased by 20% since 1994, and global oil demand is projected to grow by 1.6% per year[3].

The European Commission oriented a European energy policy on three core objectives:

- sustainability - to actively combat climate change by promoting renewable energy sources and energy efficiency;
- competitiveness - to improve the efficiency of the European energy grid by creating a truly competitive internal energy market;
- security of supply - to better coordinate the EU's supply of and demand for energy within an international context[4].

The United States and Japan have a comparative advantage in biotechnology and nanotechnology patenting and in the relevant scientific fields, while the EU is the world leader in environment-related technologies and services with special reference to recycling. Recycling: proper and effective waste management and Renewable energy-two of Leads markets of the EU. Japan is second to the EU in all three environmental technology fields[5].

Since 1990, the EU has been engaged in an ambitious and successful plan to become world leader in renewable energy. To take one example, the EU has now installed wind energy capacity equivalent to 50 coal fired power stations, with costs halved in the past 15 years. The EU's renewable energy market has an annual turnover of € 15 billion (half the world market), employs some 300,000 people, and is a major exporter. Renewable energy is now starting to compete on price with fossil fuels[6].

In the year 2010 Commission proposed new economic strategy for Europe*: Europe 2020*[7]. This Strategy presented three key drivers for growth, to be implemented through concrete actions at EU and national levels:

- smart growth (fostering knowledge, R+D, innovation, education and digital society),

[3] GREEN PAPER, A European Strategy for Sustainable, Competitive and Secure Energy, Brussels, 8.3.2006; COM(2006) 105 final, p.3; comp. also: Summary report on the analysis of the debate on the green paper "A European Strategy for Sustainable, Competitive and Secure Energy" COMMISSION STAFF WORKING DOCUMENT; Brussels, 16.11.2006 , SEC(2006) 1500

[4] As above.

[5] OECD SCIENCE, TECHNOLOGY AND INDUSTRY SCOREBOARD 16 2007 – ISBN 978-92-64-03788-5 – © OECD 2007, p.p.9-16.

[6] GREEN PAPER, A European Strategy for Sustainable, Competitive and Secure Energy, op.cit. p.11.

[7] COM(2010) 2020; Brussels, 3.3.2010.

- sustainable growth (making our production more resource efficient while boosting R+D and competitiveness);
- inclusive growth (raising participation in the labor market, the acquisition of skills and the fight against poverty).

On the 10th November 2010, the European Commission has adopted the Communication "Energy 2020 - A strategy for competitive, sustainable and secure energy" The Communication defines the energy priorities for the next ten years and sets the actions to be taken in order to tackle the challenges of saving energy, achieving a market with competitive prizes and secure supplies, boosting technological leadership, and effectively negotiate with our international partners[8].

The three most important objectives in the energy economy to be met in the EU by 2020, known as the "20-20-20" targets are as follows:

- 20% of EU energy consumption to come from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency
- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels[9].

The EU has even offered to reduce its emissions by 30% if other major economies commit to comparable emission reductions or adequate contributions. Negotiations on this are ongoing within the framework of the United Nations. In "A roadmap for moving to a competitive low-carbon economy in 2050", the European Commission also looked at new ways of reducing greenhouse gas emissions by 80 to 95% by the middle of the century.

The "Energy 2020 Strategy" provides also a solid and ambitious European framework for energy policy, defines the energy priorities for the next ten years and sets out the action to be taken.

1. Free movement of energy
   Electricity and gas are transported in grids and pipelines that often cross national borders. The energy policy decisions made by one country inevitably have an impact on other countries.

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[8] http://ec.europa.eu/energy/strategies/2010/2020_en.htm, see. also: Energy 2020A strategy for competitive, sustainable and secure energy**,** {SEC(2010) 1346}**,** Brussels, 10.11.2010; COM(2010) 639 final

[9] The EU climate and energy package,
http://ec.europa.eu/clima/policies/package/index_en.htm

2. A technological shift
   Without a technological shift, the EU will fail on its 2050 ambitions to de-carbonize the electricity and transport sectors.
3. Strong International Partnership
   International energy policy must pursue the common goals of security of supply, competitiveness and sustainability.

While relations with producing and transit countries are important, relations with large energy-consuming nations and particularly emerging and developing countries are of growing significance[10].

3. Powering Development with Renewable Energy Technologies (RETs)

The role of RET-s in the world economy is still increasing. According to UNCTAD, Technology and Innovation Report (2011) the total renewable power capacity (including wind-, biomass-, solar- and geo-thermal power) belong in 2/3rd to developed market economies and in 1/3rd to developing countries[11].

Technological progress and greater investments and deployment are lowering costs of established RET-s. Global Investments in renewable energy and related technologies during the period 2004-2010 increased from 33 to 211 $ billion. The average annual growth rate amounted to 38,3%[12]. The green economy and Rio+20 framework should promote wider use and learning of RETs.

National Policy Frameworks for Renewable Energy Technologies (according to UN and EU regulations) are mostly oriented on:

- Defining policy strategies and goals;
- Enacting policy incentives for R&D, innovation and production of RETs;
- Enacting policy incentives for developing greater technology absorptive capacity, which is needed for adaptation and use of available RETs;
- Promoting domestic resource mobilization for RETs in national contexts;
- **Exploring newer means of improving innovation capacity in RETs, including North-South and South-South collaboration.**

[10] http://europa.eu/pol/ener/index_en.htm

[11] Technology and Innovation Report (2011),*Powering Development with Renewable Energy Technologies*, United Nations, New York, Geneva, 2011, p. 8-9.

[12] as above, p.10.

4. Liberalization of markets for energy products is also one of the most important objectives of the WTO

Much of today's energy supply — particularly fossil fuels and natural gas — is geographically concentrated, fixed in terms of location, and prominent in the production and trade of the countries that possess the resource. Thus, trade patterns on the supply side are largely pre-determined and change only slowly, in contrast to the shifting comparative advantage we associate with economies that are less resource-endowed in this way.

But compared to the geographical concentration that characterizes the supply side of energy markets, demand is very widely spread because we all need energy to run our economies. This relationship between supply and demand has important implications for the economic and political conditions under which trade takes place. We observe in the world economy some significant changes that are occurring in energy markets, and which some argue fortify the case for closer attention on the part of the WTO to the energy sector. Over time, a larger number of players have entered the field on the supply side. In no small part this is the result of technological advances and the diversification of energy sources. Fossil fuels and natural gas increasingly compete with alternative energy sources such as nuclear power and renewable energy, including bio-fuels, wind, water and solar power.

5. Detoxifying Finance and De-carbonization the Economy: Opportunities for Clean and Sustainable Growth in Developing and Transition Economies- main problems

- A transition to a low-carbon and more resource –efficient economy provides a promising avenue for economic and social development in many countries,
- Promoting sustainable agriculture, enhancing energy efficiency and harnessing renewable energy for sustainable rural development are but three illustrative poles that could yield a triple win: economic growth, job and income creation, as well as environmental sustainability.
- Despite the fact that such investments are strategic and can be lucrative, the greening of economies requires the elimination of perverse policy frameworks as well as the availability of public finance where public investment is deficient.

- It will also require the emergence of the necessary awareness, skills, capabilities and vision to mobilize the private sector, governments, and the society as a whole[13].
- A „new economic growth" (within the current global and financial crisis) can only emerge if inspired leadership is manifest among a critical mass of countries. Policy measures that undermine change must be reformed or eliminated, such as subsidies (e.g.) to agriculture or energy), domestic energy policy (energy pricing), as well as national investment policies[14].
- Liberalization of climate –friendly technologies, goods and services would contribute not only to increasing the choices available to importing countries, but also lowering the costs of those choices, thus making it easier to mitigate climate change. However, finding a viable negotiating strategy for the liberalization of these goods has proved difficult in the WTO[15].
- Agriculture accounts for 13 percent of global GHG emissions. This rises to almost 30 per cent if land clearance for farming, agrochemical production and trade in agricultural and food products are attributed to the sector[16].
- Innovative management options, such as organic farming, offer promising opportunities to reconcile the objectives of feeding a rapidly growing human population with minimal adverse impacts on the environment[17].
- Methane is a significant contributor to climate change, and the bulk of methane emissions, i.e. 52%, are emitted by the agricultural sector. While methane emissions in the OECD countries as well as in the CIS have declined over the past decade, methane emission have been increasing in many developing countries and regions. With continuing growth in the demand for livestock products, methane will constitute a large proportion of future GHG emissions, particularly in developing countries[18].

[13] Trade and Environment Review 2009/2010, United Nations, New York, Geneva,2010, p. 3.
[14] As above, p. 23.
[15] As above, p. 17
[16] As above, p. 67
[17] As above., p.112
[18] As above, p. 124

6. Agriculture and environmental protection

Integrating environmental concerns into the Common Agricultural Policy aims to head off the risks of environmental degradation and enhancing the sustainability of agro-ecosystems.

Around half the EU's land is farmed. Farming is important for the EU's natural environment. Farming and nature influence each other:

- Farming has contributed over the centuries to creating and maintaining a unique countryside. Agricultural land management has been a positive force for the development of the rich variety of landscapes and habitats, including a mosaic of woodlands, wetlands, and extensive tracts of an open countryside.
- The ecological integrity and the scenic value of landscapes make rural areas attractive for the establishment of enterprises, for places to live, and for the tourist and recreation businesses.

The links between the richness of the natural environment and farming practices are complex. Many valuable habitats in Europe are maintained by extensive farming, and a wide range of wild species rely on this for their survival. But inappropriate agricultural practices and land use can also have an adverse impact on natural resources, like

- pollution of soil, water and air,
- fragmentation of habitats and
- loss of wildlife.

The Common Agricultural Policy (CAP**)** has identified three priority areas for action to protect and enhance the EU's rural heritage:

- Biodiversity and the preservation and development of 'natural' farming and forestry systems, and traditional agricultural landscapes;
- Water management and use;
- Dealing with climate change.

The CAP ensures that its rules are compatible with environmental requirements and that CAP measures promote the development of agricultural practices preserving the environment and safeguarding the countryside. Farmers are encouraged to continue playing a positive role in the maintenance of the countryside and the environment.

This is achieved by:

- targeting aid at rural development measures promoting environmentally sustainable farming practices, like agri-environment schemes;

- enhancing compliance with environmental laws by sanctioning the non-respect for these laws by farmers through a reduction in support payments from the CAP[19].

EU farm policy – known as the common agricultural policy – ensures adequate European food production goes hand in hand with economically viable rural communities and action on environmental challenges such as climate change, water management, bioenergy and biodiversity[20].

Today, EU policy aims to enable producers of all forms of food – whether cereals, meat, dairy, fruit, vegetables or wine – to:

- produce sufficient quantities of safe, high-quality food for European consumers,
- make a full contribution to diversified economic development in rural areas,
- meet very high standards of environmental care and animal welfare.

With consumers becoming ever more quality-conscious about food, voluntary EU quality marks now help them make educated choices. These labels – indicating geographic origin, use of traditional ingredients or methods, including organic – also help make EU farm products competitive on world markets.

The various reforms of EU farm policy have also promoted innovation in farming and food processing – aided by EU research projects that have increased productivity and reduced environmental impacts, e.g. by using crop by-products and waste products to produce energy[21].

With about 40 % of the EU's land area being farmed, agriculture has a very important impact on the natural environment:

- Over the centuries, farming has created and maintained a variety of valuable semi-natural habitats on which a wide range of wildlife depend for their survival.
- Farming practices can have an adverse impact on natural resources, such as pollution of soil, water and air, fragmentation of habitats, and a loss of wildlife[22].

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[19] http://ec.europa.eu/agriculture/envir/index_en.htm

[20] http://europa.eu/pol/agr/index_en.htm

[21] Agriculture and bioenergy, http://ec.europa.eu/agriculture/bioenergy/index_en.htm

[22]http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/introduction

7. Agriculture and Bioenergy

The EU is committed to combat climate change and to increase security of its energy supply. Bioenergy from forestry and agriculture plays a key role for both. The Common Agricultural Policy helps agriculture and forestry to provide biomass for energy and encourages the use of bioenergy in rural areas[23].

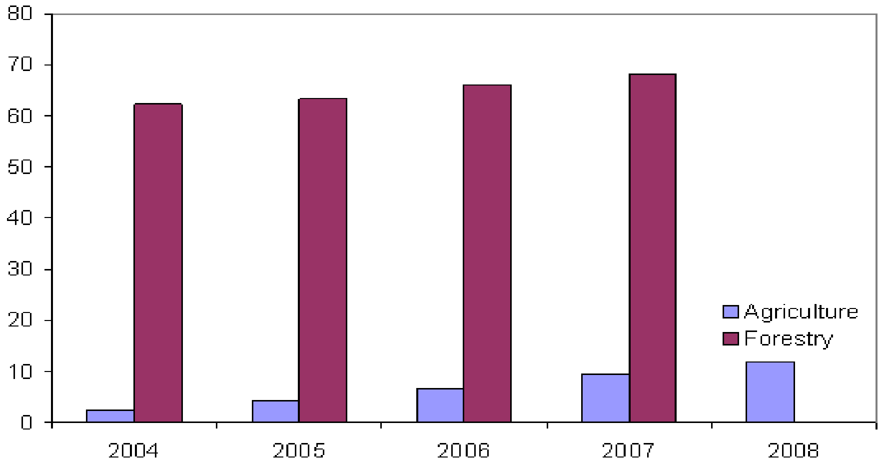
Basic issues related to the bioenergy

- Bioenergy is one form of renewable energy among many from other sources (wind, solar, hydraulic, geothermal etc).
- Bioenergy, if produced sustainably, saves greenhouse gas emissions.
- Bioenergy accounts for more than two thirds of total renewable energy in the EU.
- Biomass for energy is mainly provided by forestry (which provides half of the EU's renewable energy), agriculture and organic waste. The share of agriculture – although still modest – is growing fast.
- Feedstocks for bioenergy are storable; bioenergy can thus be produced constantly and is a reliable source of energy.
- Biomass is amply available in most parts of Europe.
- Biomass can be either in solid, liquid or gaseous form and can be used to produce electricity, direct heating, or transport fuels[24].

[23] Agriculture and bioenergy, http://ec.europa.eu/agriculture/bioenergy/index_en.htm

[24] http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/introduction

Graph 1. Production of energy from EU forestry and agriculture, million tonnes oil equivalent



Sources: Forestry – Eurostat, Agriculture – EC DG Agriculture and Rural Development, based on eBio, EBB, EurObserv'ER.

8. Interrelations between the EU sustainable energy and sustainable agriculture policies

The two main objectives of EU energy policy are increasing security of energy supply and reducing greenhouse gas emissions.

Central piece of legislation is the Renewable Energy Directive 2009/28/EC. It sets ambitious binding targets for all Member States such that the EU will reach a 20% share of renewable energy by 2020. For the transport sector, it sets a specific minimum 10% target for each Member States. The Directive also establishes a comprehensive sustainability scheme for biofuels.

The Directive requires Member States to plan their development of each types of renewable energy, including bioenergy, by elaborating National Renewable Energy Action Plans. Moreover, provisions for cooperation between Member States help them to achieve their targets more cost-effectively.

Member States were obligated to transpose the Directive in their national legislation by December 2010[25].

The starting point, the renewable energy potential and the energy mix of each Member State vary. It is therefore necessary to translate the Community 20 % target into individual targets for each Member State, with due regard to a fair and adequate allocation taking account of Member States' different starting points and potentials, including the existing level of energy from renewable sources and the energy mix. It is appropriate to do this by sharing the required total increase in the use of energy from renewable sources between Member States on the basis of an equal increase in each Member State's share weighted by their GDP, modulated to reflect their starting points, and by accounting in terms of gross final consumption of energy, with account being taken of Member States' past efforts with regard to the use of energy from renewable sources[26].

By contrast, it is appropriate for the 10 % target for energy from renewable sources in transport to be set at the same level for each Member State in order to ensure consistency in transport fuel specifications and availability. Because transport fuels are traded easily, Member States with low endowments of the relevant resources will easily be able to obtain biofuels from elsewhere. While it would technically be possible for the Community to meet its target for the use of energy from renewable sources in transport solely from domestic production, it is both likely and desirable that the target will in fact be met through a combination of domestic production and imports. To this end, the Commission should monitor the supply of the Community market for biofuels, and should, as appropriate, propose relevant measures to achieve a balanced approach between domestic production and imports, taking into account, inter alia, the development of multilateral and bilateral trade negotiations, environmental, social and economic considerations, and the security of energy supply[27].

The improvement of energy efficiency is a key objective of the Community, and the aim is to achieve a 20 % improvement in energy efficiency by 2020. That aim, together with existing and future legislation including Directive 2002/91/EC of the European Parliament and of the Council of 16

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[25] DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC(Text with EEA relevance), Official Journal of the European Union, L 140/16 EN Official Journal of the European Union 5.6.2009.

[26] as above p.15.

[27] as above p. 16.

December 2002 on the energy performance of buildings, Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of eco-design requirements for energy-using products, and Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services, has a critical role to play in ensuring that the climate and energy objectives are being achieved at least cost, and can also provide new opportunities for the European Union's economy. Energy efficiency and energy saving policies are some of the most effective methods by which Member States can increase the percentage share of energy from renewable sources, and Member States will thus more easily achieve the overall national and transport targets for energy from renewable sources laid down by this Directive[28].

Emissions of methane (CH4) and nitrous oxide (N2O) from agriculture

Sustainable development and the integration of environmental considerations into European Commission policy instruments have been identified as long-term targets for the EU, as expressed in the 6^{th} Environmental Action Programme and the EU Sustainable Development Strategy[29]. Globally, the ultimate aim of the UN Framework Convention on Climate Change (UNFCCC) is to limit atmospheric concentrations of greenhouse gases to levels such that anthropogenic interference with the climate system is minimized, while ensuring sustainable levels of economic development can occur[30]. Like any other economic sector, agriculture produces greenhouse gases and is a major source of the non-CO_2 greenhouse gases methane and nitrous oxide. Both of these gases are many times more powerful greenhouse gases than CO_2. The aim of this indicator is therefore to present the contribution of the agriculture sector to total emissions of EU-15 greenhouse gases.

- Agriculture contributed 10.1 % of the total EU emissions of greenhouse gases in 2002 Ireland (27%), France (18%) and Denmark (15%) had

[28] as above. p.17.

[29] *VI Program Działań Wspólnoty Europejskiej* w *Dziedzinie Ochrony Środowiska-Środowisko 2010: Nasza przyszłość, Nasz wybór,* Artykuł 2, propozycja decyzji Parlamentu Europejskiego i Rady ustanawiającej Program Działań Wspólnoty w Dziedzinie Ochrony Środowiska na lata -2001-2010. s. 66. cyt za: Wysokinska Z., Witkowska J., Integracja Europejska. Dostosowania w Polsce w dziedzinie polityk, PWE, Warszawa, 2004.rozdział p.t. Dostosowania w Polsce do polityki ochrony środowiska Unii Europejskiej.

[30] United Nations Framework Convention on Climate Change, http://unfccc.int/resource/docs/convkp/conveng.pdf

respective contributions of agriculture emissions to total greenhouse gas emissions significantly higher than the EU average[31].

- In absolute amounts, the agriculture sector produced 416 413 ktonnes CO_2 equivalent of greenhouse gases in 2002, an 8.7 % reduction compared with 1990 emissions.
- Reductions in greenhouse gas emissions were mainly due to a 9.4 % reduction in methane enteric fermentation emissions because of a reduction in livestock numbers, and an 8.2 % reduction in nitrous oxide emissions from agricultural soils because of a decrease in the use of nitrogenous fertilisers[32].

9. Conclusions

The main objectives in the world- and in the European Economy:- promoting poles of clean growth to foster the transition to a more sustainable economy. Sustainable development and ”green economy” are the most important objectives of economic and social development for the nearest 10 years future not only in the European but also in the world economy.

Europe as a leader in environment related technologies promotes sustainable growth and integrated environmental goods and services standards within the new industrial policy and strategy oriented on the cooperation with developing world.

The role of Renewable Energy Technologies in the world economy is still increasing. Energy efficiency; sustainable agriculture; renewable energies for rural development belong to main poles of sustainable development in the world economy and its regions.

Agriculture is one of the economic sectors to which the EU commitment to reduce emissions of greenhouse gases applies. Like any other economic sector, agriculture produces greenhouse gases and is a major source of the non-CO_2 greenhouse gases methane and nitrous oxide.

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[31] IRENA 34, Share in agriculture of gas emission, http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/documents/IRENA%20IFS%2034.1%20%20Share%20of%20agriculture%20in%20GHG%20emissions_F.pdf

[32] IRENA 19 - Emissions of methane (CH4) and nitrous oxide (N2O) from agriculture http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/documents/IRENA%20IFS%2019%20-%20GHG%20emissions_FINAL.pdf; comp. also with analysis presented on p. 9 of this paper.

It is also the strong relationship between the sustainable agriculture sector and the renewable energy development possibilities. The sustainable agriculture can be seen as a source of renewable energy. Agriculture has greatly enhanced the extraction of food energy from nature. However, if agriculture is to be a *sustainable* source of energy for food or fuel, we must first create a sustainable agriculture.

A sustainable agriculture, like all other sustainable development, must meet the needs of the present without diminishing opportunities for the future. It must be ecologically sound, because all agricultural productivity originates in the land – in the resources of nature. It must be socially responsible, because the fundamental purpose of agriculture is to meet the needs of people – not just consumers but also farmers and society in general. It must also be economically viable for farmers. All economic value originates in nature and society. The economy produces nothing; it simply facilitates our relationships with nature and society. So, an economically viable agriculture must be ecologically sound and socially responsible.

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http://europa.eu/legislation_summaries/energy/european_energy_policy/l27062_en.htm

IRENA 19 - Emissions of methane (CH4) and nitrous oxide (N2O) from agriculture http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/documents/IRENA%20IFS%2019%20-%20GHG%20emissions_FINAL.pdf; comp. also with analysis presented on p. 9 of this paper

IRENA 34, Share in agriculture of gas emission, http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/documents/IRENA%20IFS%2034.1%20%20Share%20of%20agriculture%20in%20GHG%20emissions_F.pdf

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Streszczenie

WZAJEMNA ZALEŻNOŚĆ MIĘDZY POLITYKAMI WSPIERANIA ZRÓWNOWAŻONEJ ENERGII I ZRÓWNOWAŻONEGO ROLNICTWA- Z PUNKTU WIDZENIA PERSPEKTYWY GLOBALNEJ I EUROPEJSKIEJ

Celem artykułu jest zaprezentowanie z perspektywy globalnej i europejskiej związków między sektorem zrównoważonej gospodarki energetycznej, w tym w szczególności sektorem energii odnawialnej a sektorem rozwoju zrównoważonego rolnictwa .

W gospodarce światowej i europejskiej zaznacza się w ostatnich latach systematyczny wzrost znaczenia technologii na rzecz rozwoju energetyki odnawialnej. Głównymi dziedzinami zrównoważonego rozwoju gospodarki światowej i jej regionów będą w nadchodzących latach będą te obszary, które bazują na poprawie efektywności energetycznej, zrównoważonym rolnictwie, odnawialnych energiach ukierunkowanych na rozwój obszarów wiejskich. Rolnictwo jest jednym z wiodących obszarów, do których odnoszą się ustalenia UE dotyczące redukcji emisji gazów cieplarnianych do atmosfery. Podobnie jak i inne sektory gospodarki, rolnictwo jest źródłem emisji nie tylko gazów cieplarnianych ale jest i emitentem innych gazów takich jak metan oraz podtlenek azotu. Istnieje też silna zależność między zrównoważonym rozwojem rolnictwa i możliwościami pozyskiwania energii ze źródeł odnawialnych, ponieważ zrównoważone rolnictwo wydaje się być również istotnym źródłem energii odnawialnej.

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Green Public Procurements (GPP) as an Instrument of Implementation of Sustainable Development. Analysis of the Experience of the Łódź Region Local Government.

Abstract

This paper discusses the situation on the Polish green public procurements (GPP) market, with special emphasis on the results of a GPPinfoNET project realised in the Łódź region. The identification of the main barriers hindering the application of GPP in the Polish practice is the departure point to formulating recommendations concerning organisational and legal changes which would make it possible to increase the share of GPP in the Polish economic practice. Implementation of green public procurement is considered as an important element of sustainable development.

1. Introduction

The realisation of sustainable development necessitates wide engagement of various social groups and authorities of all levels. It involves including appropriate criteria in decision-making processes related to production, consumption or realisation of public procurements. The public procurement market in OECD countries is estimated to be 12% of GDP on average; however, only 57% of the states within this group use the definition of green procurement.

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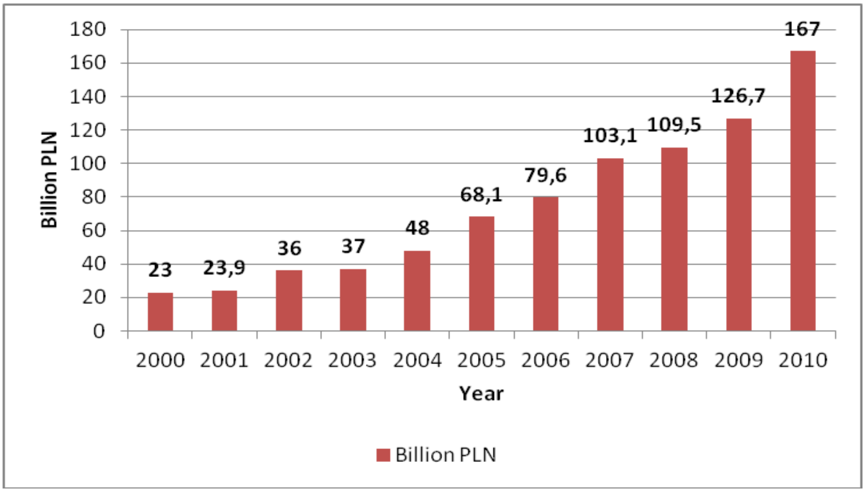
This paper discusses the situation on the Polish GPP market, with special emphasis on the results of a GPPinfoNET project realised in Poland in the Łódź region. The identification of the main barriers hindering the application of GPP in the Polish practice is the departure point to formulating recommendations concerning organisational and legal changes which would make it possible to increase the share of GPP in the Polish economic practice. This should contribute to the wider implementation of sustainable development in Poland and help reduce the gap between Poland and the leaders in the implementation of green public procurement in the EU market. The EU's Renewed Sustainable Development Strategy commits to "aiming to achieve by 2010 and EU average level of Green Public Procurement equal to that currently achieved by the best performing Member States". On this basis, in 2008 the EU Commission's Communication on Public Procurement for a Better Environment proposed a target of 50% of all the EU's public procurement tendering procedures to be "green" by 2010 – "where green means compliant with endorsed common GPP criteria".

2. Public procurement market in Poland

Subsequent reports of the Public Procurement Office, indicate that the public procurement market shows a growth trend (fig. 1) and it is a substantial source of the GDP. In 2010 it reached the value of PLN 167 billion, which means a 32% increase in relation to 2009, when the value of public procurements was PLN 126.7 billion. The works constituted 43%, supplies 20%, and services 37% of the value of the contracts awarded. Its functioning is based on the Act of 29 January 2004 - Public Procurement Law (Journal of Laws of 2010, No. 113, item. 759; No. 161, item. 1078 and No. 182, item 1228 and of 2011, No. 5, item 13, No. 28, item 143 and No. 87 item 484) and 15 other legal acts (Annex 1).

Figure 1. Public procurement market in Poland in years 2000-2010



Source: Reports of Public Procurement Office.

The need to comply with regulations spread over various acts and regulations related to them, the need to assure compliance of the Polish law with the EU regulations, and frequent modifications of the law make officials get lost in the legal complexities. Only in 2010 the regulations of the Public Procurement Law act were modified five times, and the huge documentation (with numerous enclosures), required in the case of procurements exceeding 14,000 Euros, changes public procurement procedures into a genuine obstacle course. Currently in Poland orderers give their orders on the basis of an individual (each-time) assessment (Paragraph 22 item 1 of the Public Procurement Law) of the tenderer's qualifications, knowledge and experience, as well as their technical and human-resource potential and their economic and financial situation. Documenting the compliance with the above-mentioned requirements is always the tenderer's responsibility, while their assessment is the responsibility of the orderer. It must be emphasised that infringement of the procedures is liable to legal responsibility as provided in the Public Finance Act and to responsibility for infringing financial discipline. Assuring appropriate supervision of realisation of projects realised by central and local authorities is a problem. The Supreme Audit Office has indicated irregularities in project supervision in as many as 53% of all audits conducted. The situation is made more difficult by incoherent interpretation of legal regulations by courts of justice (Górnicki 2011, p. 27)

3. Green public procurements in Poland

The Polish Public Procurement Office has already twice developed action plans concerning sustainable public procurements, involving green procurements. The first one concerned the period of 2007 – 2009, and the other - 2010 – 2012.

The National Action Plan on Sustainable Procurement is a response to recommendations included in international documents in accordance with the provisions of *the Act on rules of conducting development policy,* and is also coherent with the *National Development Strategy 2007-2015.* The main goal of the *National Action Plan on Sustainable Public Procurement* is promotion of solutions for contract award procedures which can positively influence the eco-innovations and pro-social behaviour. Given the above, we can conclude that the objectives of the National Action Plan in this regard are consistent with the objectives of the *Strategy for Innovation and Effectiveness of the Economy* to be developed by the Ministry of Economy, and the Strategy for *Energy and Environmental Safety* to be developed by the Ministry of Economy in cooperation with the Ministry of Environment in accordance with the Plan of Arrangement of Development Strategies, adopted by the Council of Ministers on 24 November 2009 (National Action Plan on Sustainable Public Procurement 2010-2012, p. 3).

Green public procurement (GPP) means a policy under which public entities introduce environmental criteria and/or requirements into procurement process (contract award procedures) and seek solutions which minimise a negative impact of goods/services on the environment and consider the entire life cycle of products, and thus influence the development and dissemination of environmental technologies. Purchasing environmentally-friendly goods and services also sets a good example and influences the market by stimulating the industry to develop environmentally-friendly products and technologies. In case of certain types of goods, works and services, the impact can turn out to be particularly significant due to the fact that public procurement constitutes a high share of market segments. More "green" character of goods and services should be determined based on the life cycle, so that GPP will affect the entire supply chain and will lead to a wider application of environmental standards in private purchase [Manual *Ecological Procurement*].

The general, the objectives adopted in Poland concerning activities within GPP include:

- increase in the level of green public procurement at national level to 20% (based on the methodology of PPO);

- boost the market development by creating demand for products meeting high environmental standards and innovative environmental technologies on the part of public administration (National Action Plan on Sustainable Public Procurement 2010-2012, p.22).

Detailed objectives include:

- increase in GPP awareness, measured by the number of trained persons and increase the level of contract awarding procedures integrating environmental considerations (increase in the GPP percentage to the level of 20%, increase of trained persons by 20%);
- increase in number of units applying a verified environmental management system (EMS), (e.g. EMAS or PN-EN ISO 14001:2005) (by 20% in relation to the current state);
- increase in number of national products certified by the Polish Ekoznak and/or EU Ecolabel (by 50% in relation to the current state).

The following tools will be applied to meet the objectives specified in the Action Plan:

- training and conferences addressed to awarding entities/tenderers popularising green public procurement in consideration of Life Cycle Costing, environmental management systems, and eco-label criteria;
- preparing publications, informative materials, analyses, criteria developed based on the GPP Toolkit, and their popularisation;
- launch of a website dedicated to green public procurement;
- popularisation among awarding entities of criteria developed for specific product groups within eco-label systems (Ekoznak, Ecolabel);
- supporting trade initiatives aimed at limiting the negative impact of goods and services on the environment;
- popularisation of environmental management systems (such as EMAS, PN-EN ISO 14001:2005) and their relation to procurement (confirmation by the tenderers of meeting requirements of the awarding entity).

Monitoring changes in the scope of green public procurement will be executed by means of the following benchmarks:

- quantitative and monetary share of procurement integrating environmental aspects based on the methodology of the PPO;
- number of Polish entities registered in EMAS;
- number of Polish entities having the certificate PN-EN ISO 14001: 2005.
- number of Polish products labelled with the Polish Ekoznak;
- number of Polish products labelled with the EU Ecolabel;
- number of participants of training events and conferences directly or indirectly;

- related to green public procurement;
- number of entries on the website www.zielonezamowienia.gov .

On 1st December 2011 a meeting of the Advisory Group on Green Public Procurement was organised in Warsaw by the European Commission (DG Environment) with organisational support of the Polish Public Procurement Office. During the meeting, preliminary results of analysis of greening public procurement in the EU Member States were presented.

Despite ambitious plans and the precise formulation of operating methods the scale of green public procurement in Poland is not impressive. That is why valuable contribution to investigate why it is so, GPPinfoNET project was implemented in Lodz.

4. The GPPinfoNET 2010 – 2011 project

The GPPinfoNET project was realised within the LIFE+ project. Its purpose was to reach public entities with information on the possibilities to use the aspects of environmental protection in public tenders, and spreading the knowledge of the Polish and EU legal regulations concerning GPP. The project was coordinated by the Cremona province in Italy, and other entities involved in the project also included the Liguria and Sardinia regions, the Italia Local Agenda 21 Association and the Ecosistemi organisation. In Poland, the institutional partner and the project coordinator was the City of Łódź in cooperation with the European Regional Eco-Hydrology Center of the Polish Academy of Science (Europejskie Regionalne Centrum Ekohydrologii PAN) under the UNESCO auspices. The most measurable effect was creating a platform to exchange information on using GPP as an instrument of environmental protection and sustainable development of towns and regions.

In the Łódź region, 38 subjects joined the cooperation within the GPPinfoNET network. Other partners included: Public Procurement Office, The Union of Polish Metropolises, Regional Fund for Environmental Protection and Water Management in Łódź, four higher education institutions and universities, local governments from the Łódź region and NGOs. Proceedings and reports on training meetings and workshops are available on the following websites: http://uml.lodz.pl/miasto/czystosc_i_ekologia/ekologiczne_zamowienia publiczne, http://gppinfonet.it/?p=EuropeanNeteworks – Poland&lang=en.

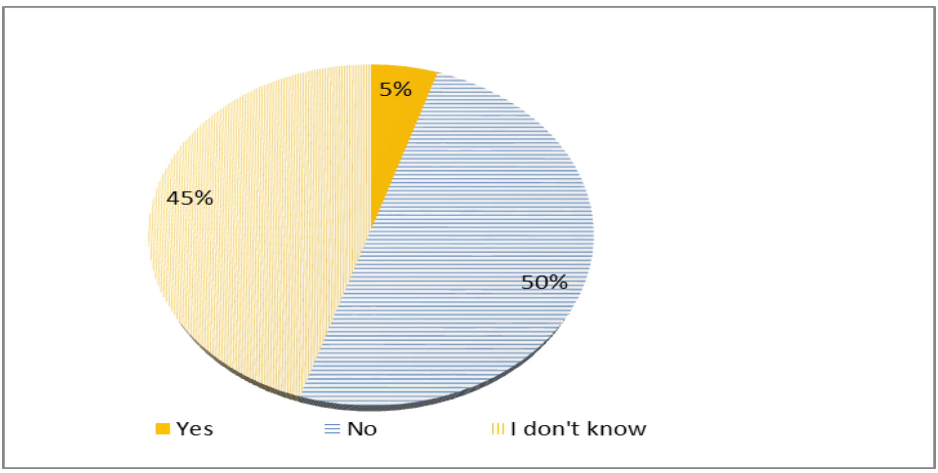
The conversations and surveys conducted during the meeting indicate that the most promising areas of GPP implementation are considered to be the following:

- technologies for rational water management;
- actions for reducing waste and strategies for waste management;
- using ecological signs;
- implementation of environmental management systems;
- product life cycle analyses.

A detailed analysis of responses to survey questions leads to formulating several interesting conclusions.

Before participating in the GPPinfoNET meetings as many as 50% respondents did not have any knowledge of the possibilities to use ecological criteria in public procurements, 45% had some knowledge of it, and only 5% considered they had sufficient knowledge.

Figure 2. Knowledge about GPP before the project



Source: Report on results of the evaluation survey delivered the second meeting of the Lodzkie GPP Network (20 respondents) – The Green Public Procurement Conference 26.10.2010 in Lodz.

As many as 80% of the project participants did not know that *The National Action Plan on Sustainable Procurement* existed. Only 10% of organisations had participated in a public tender with the implementation of the GPP procedure.

The inferior knowledge of GPP is, however, understandable, if we get acquainted with the concerns expressed by the respondents in relation to the decision criteria other than the lowest price. The list of barriers in using GPP includes, among others:

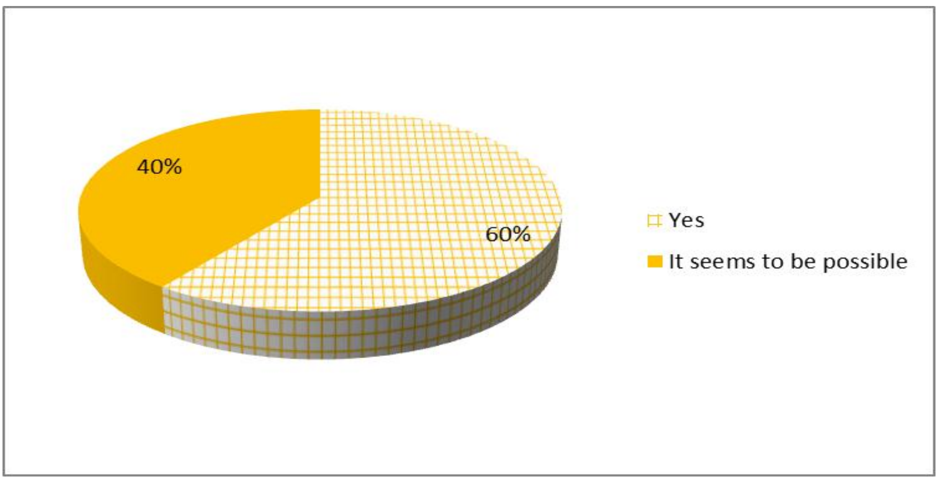
- higher values of ecological orders in relation to situations when ecological criteria are not used,

- unsystematic law in this respect,
- apprehension of realising the tender in a non-standard way,
- low ecological awareness of the society and the authorities (mentality),
- lack of information,
- problems with interpretation of legal regulations,
- lack of guidelines and appropriate publicising of the GPP idea.

The most frequently indicated barrier was the lack of appropriate legal regulations, generating concerns of potential allegations of not applying the principles of competitiveness when choosing certain products or services. The need to formulate objective decision criteria was also indicated in the context of assuring transparency of procurements and protection against allegations of corruption.

The respondents also emphasised the vast potential related to GPP in the area of implementation of ecological policy and the actual reduction of environmental pressure (95% of positive responses). GPP was also considered to be an important instrument of supporting the local market by stimulating eco-innovation, as well as an opportunity to promote one's ecological image (60% indications).

Figure 3. Possibility of using green procurement in strengthening local markets, stimulating eco-innovation and promotion

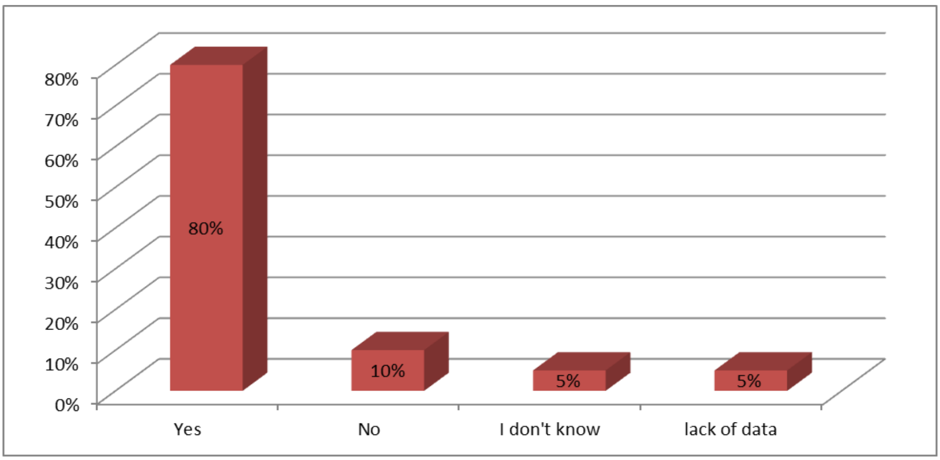


Source: Report on results of the evaluation survey delivered the second meeting of the Lodzkie GPP Network (20 respondents) – The Green Public Procurement Conference 26.10.2010 in Lodz.

Project activities also helped to investigate the perception of the effects of green public procurement in the field of environmental protection. To the question: do you think that Green Public Procurement will be enable to support activities related to the implementation of environmental protection in institutions represented by you, the majority of respondents indicated "yes" (80%). The main reasons for selecting the respondents as indicated by the presented view, saying that this:

- will be decrease the amount of hazardous waste,
- effect of scale will be used what can increase the supply for ecological products,
- will be realized higher value added concerning of the ecological results,
- the environmental awareness will be built in greater scope.

Figure 4. Possibility of supporting activities related to the implementation of environmental protection by using green procurement

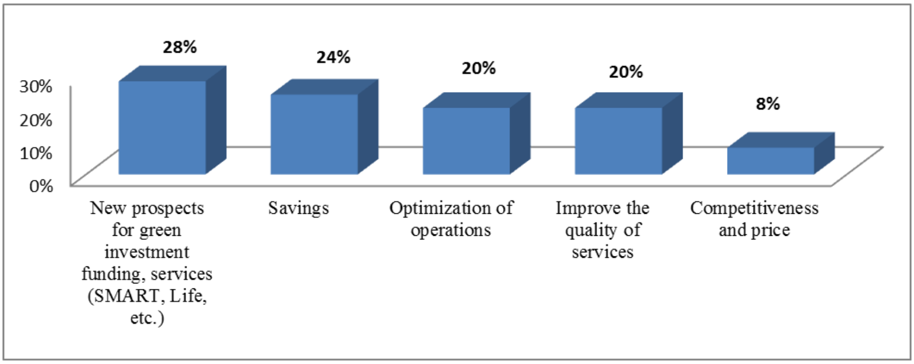


Source: Report on results of the evaluation survey delivered the second meeting of the Lodzkie GPP Network (20 respondents) – The Green Public Procurement Conference 26.10.2010 in Lodz.

Large number (90%) of respondents strongly felt the need for the dissemination of knowledge and the promotion of green public procurement, on the grounds that the possibilities afforded by this instrument of development policy, both in terms of environmental protection, promotion and building a high quality of life have a good perspectives.

The project also considered the possibility of using GPPinfoNET knowledge regarding the use of green public procurement in the context of an approach based on the concept of a Europe 2020 strategy based on an approach which integrates smart growth, sustainability and social inclusive. Tools of implementing the Europe 2020 strategy in the context of the use of the know-how of green public procurement, were taken under the discussion. It investigated that a great opportunity is using GPP in the new funding prospects for green investments, services - which will decide on European competitiveness and quality of life of Europeans (28% of responses).

Figure 5. Areas of intervention offers the greatest potential for efficient use of green public procurement



Source: Report on second phase results GPP2- evaluation survey of GPPinfoNET – Green Public Procurememnt in European Cities 28-29.12.2011 (17 respondents) in Lodz.

The project GPPinfoNET gave also very practical effects for the administration procedures of the City Lodz office in terms of legislative solutions. On 6 December 2011 The City of Lodz have adopted decree of the Mayor of the City on the new rules for planning and implementing public procurement for the City of Lodz. The new rules allow a more clear and in direct way to use environmental criteria relating to quality, functionality and application of best available technologies in the field of environmental impact, including operating costs referring to the LCA approach during determining the tender specification and verification of bids.

Moreover, the approach based on sustainable development, rational use of resources and responsible treatment of the space in which we live, including the promotion of innovative solutions, eco and public procurement which are giving limitation in scope of the environmental impact has been reflected in the adopted by the City Council of Lodz on 25th of June 2012 – the Strategy for Integrated Development of Lodz 2020 +.It is an good example on how seed capital of knowledge in relation to sustainability can be efectively put in main strategic planning documents giving a good basis for implementing real sustainable development.

Green public procurement were also identified during the public consultation of "Policy for municipal economy and environment protection" which is operational document of the Strategy for Integrated Development of Lodz 2020 + and included in this document as a tool for sustainable development and environmental protection. Also the City of Lodz is planning to implement the statistic indicator of GPP which will show the possibilities of that kind of approach.

5. Conclusions

The presence of GPP in public procurement procedures in Poland is still very low, which results mainly from two reasons. The first one is undoubtedly low awareness among potential orderers of the possibilities and the need to apply ecological criteria in public procurement. It is, without doubt, caused by the still low ecological awareness of the entire society, as well as that of authorities of different levels, when electing whom the citizens usually are not interested in ecological policy. The changes observed in this respect are happening very slowly. The other reason is related to the legal system. The "over-regulation" of procedures, frequent changes of the laws and the distinctly felt lack of confidence between the orderer and the tenderer, induce the orderer to try to reduce the number of risks to a minimum. This translates into a practice of selecting offers only from the point of view of the lowest price, which has been observed in Poland for many years. Electronic auctions or tenders are relatively seldom used. To an extent it may result from the instruction of the Central Anti-Corruption Office relating to procedures with consideration for other criteria than the price. These concerns are confirmed by research conducted in the Łódź region within the GPPinfoNET project. Therefore, the introduction of the requirement to apply ecological criteria in procurement procedures within selected industries and for selected products must be considered to be very advantageous. External obligation, e.g., from the EU level, may be an impulse for actions which in a longer perspective may be favourable for promoting eco-innovation and development of markets for environmentally-friendly products. Authorities of different levels may play a significant role in that, not only by applying GPP in their own procurements but also by promoting good practices. It is worth emphasising that thinking in the terms of the entire product life cycle terms may be profitable. It has been known for a long time that the lowest purchase price does not guarantee equally low running costs. That is why using solely the price criterion, so frequent in the Polish public procurement practice, must be considered short-sighted and socially detrimental. It is not a problem resulting for the law, which allows using other offer assessment criteria, such as functionality, technical parameters, running costs or service and maintenance. The biggest problem is still the mentality of decision-makers. Therefore, the future of GPP in Poland depends to the largest extent on the introduction of an obligatory requirement to include ecological issues in the system of public procurement, and on the success of educational actions. This will be particularly necessary in the face of the required cost cutting caused by the prolonged economic downturn in Europe. Green public procurement, because of its nature and potential scale can be a very important element in the implementation of sustainable development. In Poland, the success in this area is far from both the possibilities and social expectations.

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Annex 1. Legal framework of public procurement in Poland

PUBLIC PROCUREMENT LAW

Act of 29 January 2004 - Public Procurement Law (cosolidated text)

SECONDARY LEGISLATION

Regulation of the Prime Minister of 10 May 2011 on non- price mandatory tender evaluation criteria with respect to certain types of public contracts (Journal of Laws No. 96, item 559)

Regulation of the Prime Minister of 26 October 2010 on report on contract award procedure (Journal of Laws, No. 223, item 1458)

Regulation of the Prime Minister of 22 March 2010 on the rules regarding the procedure for examining the appeals (Journal of Laws No.48, item 280)

Regulation of the Prime Minister of 15 March 2010 on the amount of and the manner for collecting the registration fee for the appeal, kinds of costs in the appeal procedure and the manner for their calculation (Journal of Laws No. 41, item 238)

Regulation of the Prime Minister of 16 October 2008 on the standard forms of notices placed in the Public Procurement Bulletin (Journal of Laws, No. 12, item 69)

Regulation of the Prime Minister of 28 January 2010 on the list of priority and non-priority services (Journal of Laws, No. 12, item 68) Annexes

Regulation of The Prime Minister of 30 December 2009 on the types of documents which may be requested by the awarding entity from the economic operator and forms in which these documents may be submitted (Journal of Laws, No. 226, item 1817)

Regulation of The Prime Minister of 23 December 2009 on the average exchange rate of Polish zloty against Euro being the basis for converting the value of public contracts (Journal of Laws, No. 224, item 1796)

Regulation of The Prime Minister of 23 December 2009 on the value threshold of contracts and design contests which imposes an obligation of dispatching the notices to the Office for Official Publications of the European Communities (Journal of Laws, No. 224 item 1795)

Regulation of the Prime Minister of 10 September 2007 amending the regulation on the scope of information included in annual report on the conducted contract award procedures, its standard form and the manner of submission (Journal of Laws No. 175, item 1226)

Regulation of the Prime Minister of 25 August 2006 on the scope of information included in annual report on the conducted contract award procedures, its standard form and the manner of submission (Journal of Laws No. 155, item 1110)

Regulation of the Prime Minister of 2 July 2007 on the manner of conducting the qualifying procedure for members of the National Appeal Chamber, the manner of appointing the qualifying committee, as well as detailed scope of the qualifying procedure (Journal of Laws No. 120, item 820)

Regulation of the Prime Minister of 22 March 2004 on the amount of remuneration of the Chairman, Vice Chairman and other members of the Council of Public Procurement (Journal of Laws, No. 49, item 470)

LEGISLATION RELATED TO PUBLIC PROCUREMENT

Act of the 19th December 2008 on Public-Private Partnership

Act of the 9th January 2009 on Concession for Works or Service

Streszczenie

ZIELONE ZAMÓWIENIA PUBLICZNE (ZZP) JAKO INSTRUMENT WDRAŻANIA ZRÓWNOWAŻONEGO ROZWOJU. ANALIZA DOŚWIADCZEŃ WŁADZ LOKALNYCH W REGIONIE ŁÓDZKI

W artykule przedmiotem analizy jest sytuacja na polskim rynku zielonych zamówień publicznych, ze szczególnym uwzględnieniem efektów projektu GPPinfoNET realizowanego w regionie łódzkim. Punktem wyjścia do sformułowania rekomendacji dotyczących zmian organizacyjnych i prawnych służących popularyzacji ZZP jest identyfikacja głównych barier hamujących stosowanie takich zamówień w polskiej praktyce gospodarczej. Wdrażanie zielonych zamówień publicznych jest traktowane jako ważny element realizacji zrównoważonego rozwoju.

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Application of Phytoremediation in Restoring Sustainable Development to the Environment: Economic and Soil Conditions

Abstract

The objective of this article is a presentation of priority questions and relations involving economic and soil conditions for the application of phytoremediation technology in restoring sustainable development to the environment. The analysis looks at the justifiability of the application of phytoremediation in restoring a balanced environment as an alternative method to costly land recultivation aimed at eliminating pollutants—a solution that is impossible in the case of large areas. The cost effectiveness of the use of phytoremediation in the recovery of trace element in the soil through the process of phytoremediation was demonstrated.

The quality of soils as found in the Voivodeship of Łódź was analyzed from the point of view of potential application of the phytoremediation method, taking into account subdivision by heavy metals found in the soils as well as their origins and properties. Grades of soil purity are presented and border values of heavy metal content were identified.

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1. Introduction

Most problems linked with environmental pollution may be solved with the involvement of plants. Possibilities for utilizing plants to transfer, accumulate, and remove pollutants from the environment, or at least decrease their mobility, have been a topic of discussion for over twenty years. Such an approach may also be used to eliminate both inorganic and organic xenobiotics, including pollutants present in the soil, water, and air. A major objective is the prevention of pollutant migration that might cause a greater threat to public health. Phytoremediation is a promising and dynamically developing technique for cleaning the environment. The technology involves the applications of plants that are potentially capable of growing in polluted soils that influence biological, chemical, and physical processes so as to eliminate xenobiotics from the environment. The range of pollutants that can be the object of phytoremediation is very broad. It encompasses inorganic fertilizer, pesticides, heavy metals trace elements and radionuclides, explosives, petroleum and other leaked liquid fuel, and even compounds used in chemical weapons. Substances disrupting the hormone economy (endocrine disrupting compounds – EDCs) such as tributyltin, bisphenol A, and nonylphenol are also objects of interest as are the very difficult to decompose polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). Plants often use pathways and enzymes similar to those present in mammals. This is behind the emergence of the concept of a “green liver.” However, plants are phototrophic organism and are not capable of achieving the complete mineralization of organic particles. They do not use essential compounds in the carbon and energy metabolism and as a consequence the lack the normal catabolic enzymes vital in this process. In practice, this means that plants are not capable of metabolizing organic compounds into basic products such as CO_2 and H_2O (Singh et al. 2009)

The mechanical removal of pollutants and chemical engineering are very expensive, difficult, and simultaneously destroy the structure of the soil and lower its fertility (Shi and Cai, 2009). Utilization of plant systems to eliminate toxic components from the soil seems to be more effective and, in many aspects, better solution. Phytoremediation is cost effective, environmentally friendly, and may be applied to extremely large areas. The method also has its disadvantages because the process proceeds slowly, usually requiring several years or even decades in certain cases to decrease heavy metal pollutants by one–half. Moreover, methods for utilizing or applying biomass enriched with heavy metals are insufficiently developed (Shi and Cai 2009). The only solution that allows for the complete cleaning of the soil from heavy metals while simultaneously eliminating the disadvantages of phytoremediation is growing plants for energy purposes. Such a combination may generate profits and serve as a method for cleaning that are areas many hectares in size.

The goal of this article is the presentation of justification for the application of phytoremediation in restoring a sustainable environment as an alternative to the costly mechanical removal of pollutants, which is impossible in the case of large areas of soil.

2. The cost effectiveness of phytoremediation in recovering trace elements from the soil

Something of a discourse has been underway in the scientific community as to what plant types are best suited for phytoextraction—hyperaccumulators or plants with very large biomass (Dickinson et al. 2009; Chaney et al. 1997; Ebbs et al. 1997; Kayser et al. 2000). In many cases, the quantity of accumulated trace elements in the plant is, in the final analysis, the same—i.e. hyperaccumulators can accumulate significantly more trace elements per unit mass, but at the same time the biomass harvested is significantly lower. There is also the question of the tolerance of the plant to the presents of trace elements in the soil. In the case of major contamination, hyperaccumulators work better. As a rule, they are more resistant to pollutants. Hyperaccumulators also hold the advantage when the goal of phytoextraction is the recycling of a specific trace element. The operation involving the growing of plants accumulating a given element or group of elements that have a large concentration in the soil followed by their recovery from ashes resulting from the burning of the plants is called *phytomining*. It differs from phytoremediation in that it is also applicable to elements such as gold or platinum with a very limited presence in the surface soil. The cost effectiveness of this method depends on many factors, including the level of accumulation of the metals in the soil, the plants, and the biomass harvest. However, the most important economic factor is the value of the recovered metal. This may range from approximately PLN 172.000 per kg^{-1} in the case of gold to somewhat more than PLN 6 per kg^{-1} for lead. The phytomining method has been deemed cost effective for gold, thallium, cobalt, and nickel, where only the last is a true problem for the environment. The costs of extraction of other trace elements, such as zinc, using the discussed method are not favorable (Chaney et al. 2007; Vangronsveld et al. 2009; Sheorana et al. 2009). The phytoextraction market for trace elements is growing and is estimated to have increased in value from USD 15–25 million in the year 2000 to USD 70–100 million in the year 2005 (Glass 2000). Small plants with a capacity for hyperaccumulation of elements and a significant tolerance to their high concentration in the soil are used in phytomining. Thus, cost effectiveness is mainly dependent on the price of the extracted element. Calculating the profitability of application of phytoextraction using energy plants is significantly more difficult. The trace element content may have an impact on the volume of the plant harvest. The biomass of energy plants is many times greater as compared to hyperaccumulators, but their pollutant content per kilogram of dry matter will be lower. This may be a significant impediment to recycling. Applying the principles of the multiple land use (MLU) system, both biophysical and economic aspects should be examined. This means that in the first phase what is taken into account is the number of tons of soil protected against erosion and the number of species of plants to be placed in the habitat. In the second, profits from specific ways of management are calculated. It is estimated that Europe and the United States have several hundred thousand hectares of soil polluted by heavy metals. The phytoremediation market is estimated at approximately USD 36–54 billion, of which USD 1.2–1.4 billion involves the spontaneous removal of heavy metals from the soil (Glass 1999). Current estimates regarding the size of the area polluted by heavy metals requiring new ways of development may be significantly greater if stricter European Commission (EC 2002) requirements as to soils designated for the growing of plants for consumption are taken into account. The application of phytoremediation using the willow, taking into account MLU principles, is cost effective in the case of farmers and local authorities. Among other things, cost effectiveness is dependent on the value of product that may be produced on the soil following its cleaning through the process of phytoremediation, the time needed for its production, and the costs of investments incurred to date on the polluted area (e.g. an irrigation system). The analysis also takes into account the time needed to lower the heavy metal content to a safe level as well as revenues from the sale of biomass and subsidies, growing costs, and the costs of managing the polluted wastes derived from burning. Calculated benefits from applying phytoremediation are also dependent on the methodology used for estimates (Lewandowski et al. 2006).

Improved phytoextraction is becoming an economically viable and potentially broadly applicable technology for cleaning large areas of land of heavy metals on which decreasing the quantity of pollutants using mechanical methods known to date is impossible. Depending on the level and type of pollution as well as geographical location, the most efficient plant species may be used. The use of plants generating large amounts of biomass that may be utilized for energy purposes has opened up completely new possibilities and significantly improves the cost effectiveness of such a venture. This solution is especially beneficial for Poland and other countries of the European Union that are striving to limit carbon dioxide emissions by the power industry.

Unfortunately, modern methods of phytoremediation have, to date, not been applied on a large scale, where the bulk of cases use traditional methods for removing pollutants from the soil, which does not involve significant areas (Witters et al. 2009, 2012).

3. The quality of soils in the voivodeship of łódź in terms of potential for the application of the phytoremediation method

The development of civilization (industry, agriculture, transportation, mining, and urbanization) has a direct and indirect impact on changes to the chemistry of soil, water, the air, and food products. To a significant degree, these factors determine the health of the population. Especially dangerous is the process of accumulating trace cation elements, customarily called **heavy metals**. In Poland as well as the rest of the world, the most frequently observed complaints in humans are caused by the accumulation of lead (Pb), cadmium (Cd), and mercury (Hg) as well as to a lesser degree ten other trace elements, including copper (Cu), nickel (Ni), chromium (Cr), arsenic (As), fluoride (F), and beryllium (Be) (Kabata–Pendias et al., 1995). The order and proportions of passing through specific **ecosystems and food chains** may be established for all elements, especially the metallic ones. Most of these elements show a tendency for biological accumulation. Living organisms have biological barriers protecting them against excessive concentrations of chemical elements. When the operation of these barriers weakens, there is a concentration resulting in the accumulation of heavy metals in the last link of the food chain—**Man**. This occurs through the consumption of contaminated plant and animal products. It is for this reason that it is so important to take action aimed at limiting to a minimum the content of harmful elements in plant designated for eating. The most effective way is the exclusion of the production of plants designated for food on polluted arable soils and the development of the potential of such land by growing **energy crops**. Such efforts are in line with the assumptions behind Poland's energy policy up to the year 2025 according to which biomass utilization shall continue to be a basic direction of renewable energy source development.

Heavy metals occurring in the soil may be subdivided into their derivatives and sources as well as properties giving three groups (Kabata–Pendias et al. 1995):

- Lithogenic (bedrock–related material),
- Pedogenic (which can originate from various sources, but the form of their occurrence undergoes transformations as a result of soil formation processes), and
- Anthropogenic (introduced into the soil as a result of human activity and remaining in initial forms as introduced).

The bedrock of the **soils of the Voivodeship of Łódź** mainly consists of Quaternary deposits—dumped sands and clays, fluvial–glacial sands and gravel, river gravel and sand, Eolithic gravel and particulate matter as well as residual silt and clay. It is only in the southern part of the Voivodeship that bedrock consists of limestone, marl, claystone, and sandstone—Mesozoic deposits. As a result, the soils of the area have little variability with a dominance of podsolic soils (approximately 85% of the surface area of the Voivodeship). The remaining part consists of wetland and peat, brown, and black soils as well as alluvial soils (Ochal 2009).

Soils undergo degradation through a worsening of their chemical and physical properties as well as a fall in biological activity. This causes a decrease in the quantity and quality of plant biomass that can be derived from them. The total loss of useable soil value is called devastation. For the most part, land where there is a problem of significant degradation or devastation of the soil remains outside the area of productive agricultural land—withdrawn from agricultural use. The main factors posing a threat to soil quality are erosion, a fall in organic matter content, local and distributed pollution, sealing and compaction, a fall in biodiversity, and salting (COM(2006)231). The main direct and indirect anthropogenic sources of heavy metal soil pollution are the chemical industry, artificial fertilizers, and the cellulose and paper, electro–technical, coke, glassmaking, ceramic, cement and asbestos industries, and steel mills as well as coal power plants and petroleum refineries.

The use of traffic routes is an important source of soil pollution, especially lead and zinc. Among pollutants emitted by internal combustion engine drive vehicles, apart from lead and zinc, are chromium, cadmium, and platinum (Indeka and Karczun 1999, 2000). Heavy metals find their way into the environment as a result of the abrasion of tires and other vehicle parts. Moreover, lubricants used in motor vehicles can be a source of cadmium pollution along roads (Antonkiewicz and Macuda 2005; Baran et al. 2007).

Meteorological phenomena, including precipitation, have a major impact on the circulation of heavy metals in nature. Pollution, heavy metal acidic compounds, and salts cumulate in the atmosphere and are carried by it to be dumped on soil surfaces or on water. To a great extent, the concentration of these pollutants depends on the season of the year and quantity of precipitation.

Most substances (sulfates, nitrates, Kieldahl nitrogen, total phosphorus, potassium, magnesium, calcium, copper, lead, and manganese) are deposited in the soil and water during May and June precipitation. For their part, chlorides, sodium, and high concentrations of the remaining heavy metals are accumulated in winter and late autumn precipitation. Table No. 1 presents the annual surface load for the Voivodeship of Łódź by pollutants brought in through atmospheric precipitation.

Table 1. Annual pollutant surface load for the voivodeship of łódź through precipitation

	Precipitation (kg ha^{-1} $year^{-1}$)	**Total precipitation** (t)
Zinc	0.542	987.5
Copper	0.0364	66.3
Lead	0.0110	20.04
Cadmium	0.00123	2.241
Nickel	0.0045	8.20
Chromium	0.0022	4.008
Manganese	0.0316	57.57

Source: based on Institute of Meteorology and Water Management (2008), Report of the Department of Ecology of the of the Wrocław Branch Institute of Meteorology and Water Management, "Monitoring chemizmu opadów atmosferycznych i ocena depozycji zanieczyszczeń do podłoża. Wyniki badań monitoringowych w województwie łódzkim w 2008 roku (Monitoring the chemistry of atmospheric precipitation and assessing the depositing of pollutants to the surface: Monitoring research results for the Voivodeship of Łódź for the year 2008).

Conditions for agricultural production in the Voivodeship of Łódź are less favorable than the average for Poland. In spite of this, 57.2% of the surface area of the Voivodeship is occupied by arable land and orchards. Primary problems are acidity and soil conditions. Table No. 2 presents agricultural land use in the Voivodeship of Łódź.

Table 2. Land area of poland by land use: łódź and adjacent voivodeships

		Poland	VOIVODESHIP						
			Łódzkie	Kujawsko–pomorskie	Mazowieckie	Świętokrzyskie	Śląskie	Opolskie	Wielkopolskie
Agricultural land (ha)	Total	18869891	1297955	1176826	2437791	754466	638497	603216	1944707
	Arable land	13921466	1008897	994963	1723540	547925	460844	491663	1575063
	Orchards	294836	31091	15498	84054	31493	8146	3446	16971
	Permanent Meadowland	2286565	116666	84714	280052	95353	90299	68248	206259
	Permanent Pastureland	1627438	86987	47860	248780	43942	49481	18282	80669
	Agricultural: built–up	531895	41390	23571	79068	28292	19177	13136	43087
	Ponds	72326	4125	2092	4957	3873	7384	4081	6131
	Ditches	135365	8799	8128	17340	3588	3166	4360	16527

Source: based on *Statistical Yearbook of Agriculture*, Halina Dmochowska (Editor), Central Statistical Office, Department of Statistical Publications, Warsaw, 2011.

Grade I and II soils make up approximately 1% of the surface area of the voivodeship. Grade III soils account for 5%. They are primarily found in the *powiat*s (county level) of Kutno, Łowicz, and Łęczyca (9% of the surface area of the Voivodeship). Soil of the lowest quality, Grades V and VI, are dominant, especially in the southern and southeastern parts of the region (46% of the Voivodeship area). Table No. 3 presents agricultural land use in the Voivodeship of Łódź by soil quality. Soil that has been degraded and devastated by industry, including mainly power engineering, mining, and building construction, occupies approximately 4,000 ha in the Voivodeship of Łódź, but its surface area is continuously growing (Ochal 2009). Bearing in mind the specified data, it is possible to identify areas of the Voivodeship that could specialize in the production of energy crops with their simultaneous potential for cleaning pollution using the phytoremediation method.

Table 3. Agricultural land by soil quality and voivodeship

		Poland	Voivodships						
			Łódzkie	Kujawsko–pomorskie	Mazowieckie	Świętokrzyskie	Śląskie	Opolskie	Wielkopolskie
Total		18536936	1271856	1157838	2405579	742732	639364	585621	1899188
Soil Quality Grades	I	67782	97	2104	1715	18906	1189	2988	54
	II	536413	11556	29230	16360	60108	8715	43599	14440
	III	4201920	228307	367805	409860	155262	119071	199035	407835
	IV	7402942	444843	469734	892418	241474	279393	212430	682062
	V	4197220	382484	182133	683322	163488	165691	91540	485334
	VI	2114888	204569	103054	399847	100921	64105	35965	309211
	VIz	154335	15727	12021	31391	10235	7209	251	18255
Other[1]		15771	—	3778	2057	2573	1200	64	252

Source: based on Statistical Yearbook of Agriculture, Halina Dmochowska (Editor), Central Statistical Office, Department of Statistical Publications, Warsaw, 2011.

Pursuant to Central Statistical Office (GUS) data from the year 2010, soil in the Voivodeship of Łódź requiring recultivation amounted to 4,497 ha (54 ha more than in the previous year), of which 4,312 ha consisted of devastated soil while 184 was classified as degraded. The sustainable growing of selected varieties of energy plants with the highest tolerance to unfavorable environmental conditions, including the presence of heavy metals, and with phytoremediation properties, could become a widely applied method for recultivating the areas.

In addition to industrial, municipal, and motorization pollution, agriculture can also play a role in contaminating soil with heavy metals through the universal use of fertilizers. Approximately 40% of the soil of the Voivodeship of Łódź is marked by very low phosphorus content (Ochal 2009). The phosphorus fertilizers used can be a significant source of heavy metal soil pollution, especially cadmium. The average trace element content in phosphorus

[1] Land not covered by the soil classification system.

fertilizers forms the series as follows: Cd < Cu < Pb < Ni < Zn. The form of fertilizer has a significant impact on variations in content (Sady and Smoleń, 2004). This is linked with the quality of raw materials—phosphorites and apatites—used in production. Percentage growth in nutrient content—phosphorus—is accompanied by a fall in quantity of heavy metals introduced into the soil. Thus, phosphate meal and monocalcium phosphate introduce more of them than tricalcium phosphate. Systematic use of phosphate fertilizers may result in an increase in the content of cadmium in the soil that is easily accessible to plants (Gorlach and Gambuś 1997; Kabata–Pendias and Pendias 1999).

The share of potassium in the soil of the Voivodeship of Łódź is even lower than in the case of phosphorus, reaching 62% of the arable land (Ochal 2009). Depending on the form in which it is applied, potassium fertilizer may increase or decrease the quantity of heavy metals accessible to plants. The direction of this process is dependent on the type of metal and the physical–chemical properties of the soil being fertilized. The application of potassium chloride (KCl) results in a greater leaching away of cadmium, copper, lead, and aluminum (Al) as compared with the used of potassium sulfate (K_2SO_4) (Sady and Smoleń 2004).

Calcium needs of the soils of the Voivodeship of Łódź are significantly greater than the national average and it is vital for over 50% of the agricultural land area (Ochal 2009). Calcium fertilizer may contain many trace elements, including arsenic (0.2–24 ppm d.m.), lead (20–1250 ppm d.m.), and manganese (40–1200 ppm d.m.) (Kabata–Pendias and Pendias 1999).

The impact of fertilization using nitrogen on the quantity of heavy metals accessible to plants depends on the dosage and dates of application of the fertilizer (Sady and Smoleń, 2004). Soil pH is lowered and the content of available forms of heavy metals increase in the case use of fertilizers containing reduced forms of nitrogen such as ammonium sulfate and urea on plants. This results in an increase in the accumulation of these elements in plants (Gębski and Mercik 1997; Gębski 1998). Growth in the dosage of nitrogen in the soil causes an increase the accumulation of cadmium. However, no impact on the uptake of copper and lead has been demonstrated (Sady and Smoleń 2004).

From among applied fertilizers, the smallest amounts of trace elements are found in manure, while the greatest variations in their content are seen in municipal sewage. Depending on their place of origin, zinc content in municipal sewage may range from 700 to 49,000 ppm d.m., chromium from 20 to 40,6000 ppm d.m., nickel from 16 to 5,300 ppm d.m., and cadmium from 2 to 1,500 ppm d.m. Because of these differences, it is vital to test trace element content prior to using municipal sewage as fertilizer. Allowable heavy metal content in agricultural soil is presented in Table No. 4.

Table 4. Allowable heavy metal content in soils for agricultural use of sewage sludge

Chemical element	Content in soil (mg kg^{-1} d.m.)		
	Light soils	Medium soils	Heavy soils
Lead (Pb)	40	60	80
Cadmium (Cd)	1	2	3
Mercury (Hg)	0.8	1.2	1.5
Nickel (Ni)	20	35	50
Zink (Zn)	80	120	180
Copper (Cu)	25	50	75
Chromium (Cr)	50	75	100

Source: based on the Directive of the Minister of Environment of July 8, 2004 on conditions to be met in introducing sewage into waters or the earth as well as on substances that are particularly hazardous to the water environment (Journal of Laws of 2004, No. 168, item 1763).

One of the main factors influencing the form of heavy metals and their accessibility by plants is the acidity of the soil (Chłopecka 1994; Gębski 1998; Kabata–Pendias and Pendias 1999). Acidic soil most frequently causes the release of heavy metals. Very acidic and acidic soils account for over 50% of the area of Poland. To a great extent, this covers the share of very light and light soils. Very acidic and acidic soils account for 60%–80% of the area of the Voivodeships of Łódź, Mazowieckie, Podlaskie, and Podkarpackie. A special hazard is created by soils that are very acidic—a pH value below 4.5. They occupy over 40% of the agricultural use area of the voivodeships of Łódź, Mazowieckie, and Podlaskie, and over 35% of the Podkarpackie. Studies conducted over the years 2004–2007 indicate a maintaining of unfavorable tendencies in the matter of acidity of the soil in the Voivodeship of Łódź. Out of the 86,380 samples collected throughout the Voivodeship, 70% were very acidic or acidic, approximately 20% slightly acidic, and a mere 10% alkaline. The *powiat*s of Kutno and Łęczyca came out the as being the most favorable with acidic soils occupying only 37% and 45% of their area, respectively. A fall in soil pH to slightly acidic and acidic results in an increase in the concentration of mobile forms of heavy metals in a soil solution. They are available to plant and thus increase the indicator for their accumulation in tissues (Chłopecka 1994; Gębski 1998). This is caused by an increase in solubility of the chemical bonds of these elements as well as a decrease in absorption by soil colloids (Sady and Smoleń 2004). Cadmium and zinc are most susceptible to changes in the pH level. Their mobility starts to grow with a fall in pH below 6.0–6.5. Copper and lead do not demonstrate this property until pH < 5.0 (Gębski 1998).

Allowable content of heavy metals has been defined (as presented in Table No. 6) in order to protect the food chain against the harmful impact of these elements and in order to maintain balance in specific ecosystems. The basis for an environmental assessment of soil chemical properties is the reaction of individual elements of the ecosystem to various levels of pollution. It is for this purpose that three levels of soil pollution have been identified:

1) Natural chemical balance,
2) Upset chemical balance, and
3) Complete chemical degradation and significant threat to the ecological function of the soil.

Depending on the environmental factors taken into account, the values between levels 1 and 2 may vary. However, level 3 may be clearly defined for specific types of soil. Levels of selected heavy metals that cause complete chemical degradation of the soil are Cd – 5–20 mg kg^{-1}, Cu – 200–500 mg kg^{-1}, Ni – 150–600 mg kg^{-1}, Cr – 300–600 mg kg^{-1}, Pb – 1000–6000 mg kg^{-1}, and Zn – 1500–7000 mg kg^{-1} (Kabata–Pendias et al. 1995). These are critical values that rule out the proper functioning of the ecosystem, albeit significantly lower concentrations demonstrate the toxic impact of heavy metals on organisms. In the case of soil used for crop growing, especially plants designated for consumption by people and animals, the allowable levels of heavy metal pollution are significantly lower (Table No. 5).

Table 5. Boundary values for heavy metals in soils as specified in the annex to the directive of the ministry of environment on standards for soil quality

Contamination	**Group A**[2]	**Group B**[3]						**Group C**[4]	
		Depth (m ppt)							
		0–0.3	0.3–15.0		>15		0–2	2–15	
			Soil permeability (m s^{-1})						
			Above	Below	Above	Below		Above	Below
			1 10^{-7}		1 10^{-7}			1 10^{-7}	
Arsenic	20	20	20	25	25	55	60	25	100
Boron	200	200	250	320	300	650	1000	300	3000
Chromium	50	150	150	190	150	380	500	150	800
Tin	20	20	30	50	40	300	350	40	300
Zinc	100	300	350	300	300	720	1000	300	3000
Cadmium	1	4	5	6	4	10	15	6	20
Cobalt	20	20	30	60	50	120	200	50	300
Copper	30	150	100	100	100	200	600	200	1000
Molybdenum	10	10	10	40	30	210	250	30	200
Nickel (Ni)	35	100	50	100	30	210	300	70	500
Lead (Pb)	50	100	100	200	100	200	600	200	1000
Mercury (Hg)	0.5	2	3	5	4	10	30	4	50

Source: based on The Directive of the Minister of Environment of September 9, 2002 on Soil Quality Standards and Land Quality Standards (Journal of Laws of 2002, No. 165, item 1359).

Soils have been subdivided into six purity grades, where boundary values for heavy metal contents have been defined for each grade. Land throughout Poland has been described by voivodeship applying this classification system. Table No. 6 presents the percentage of individual grades of soil in the

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[2] Land that is a part of the area subject to protection pursuant to the Water Code as well as areas protected pursuant to legislation covering environmental protection if the maintaining of the current state of soil pollution does not create a threat to human health or the environment.

[3] Land classed as agricultural land, excluding land designated for ponds and ditches, forest and wooded land as well as land with shrubbery, and built–up and urbanized land, excluding industrial land, mining land, and land for traffic circulation.

[4] Industrial land, mining land, and land designated for traffic circulation.

Voivodeship of Łódź and adjacent voivodeships, taking into account the most and least polluted voivodeships in Poland. Data from the year 1999 show that soil polluted by heavy metals accounts for less than 1% of the area of the Voivodeship of Łódź, where this pollution is highest in the *powiat*s of Łódź, Grodzisk, Opoczno, Pabianice, Pajęczno, and Zgierz (Ochal 2009).

Table 6. Agricultural land surface soil layer contamination by heavy metals (%)

Voivodeship	Number of samples	Degree of soil contamination[5]							
		0	I	II	III	IV	V	0+I	II–V
Łódzkie	3426	86.2	12.1	0.9	0.3	0.3	0.0	98.4	1.6
Kujawsko–pomorskie	3042	94.7	4.8	0.5	0.0	0.0	0.0	99.4	0.6
Mazowieckie	5971	91.7	7.4	0.7	0.1	0.0	0.0	99.2	0.8
Świętokrzyskie	2133	68.5	29.2	2.2	0.0	0.0	0.1	97.7	2.3
Śląskie	2187	20.3	52.8	17.0	5.6	3.0	1.3	73.1	26.9
Opolskie	1746	73.7	23.1	2.1	0.5	0.4	0.2	96.3	3.1
Wielkopolskie	4463	89.9	9.1	0.8	0.1	0.1	0.0	99.0	1.0

Source: based on Kabata–Pendias A. and Pendias H. (1999), *Biogeochemia pierwiastków śladowych (Bio–geo–chemical trace elements)*, 2nd Edition, Revised, PWN Scientific Publishers, Warsaw.

Recommended ways of use for specific soil purity grades:

0° – Uncontaminated soil – May be used for the growing of garden plants as well as agricultural ones, especially those designated for consumption by babies and children. Such areas should be encompassed by special protection against the introduction of anthropogenic heavy metals.

I° – Soil with an increased amount of metals – May be used for the growing of all field crops, with restrictions on vegetables designated for processing and direct consumption by children.

II° – Slightly contaminated soil – Plants grown on such soils may be chemically contaminated. For this reason it is necessary to exclude certain vegetables—e.g. cauliflower, spinach, lettuce, etc.—from being grown on them. However, cereals, root vegetables, and forage may be grown, and use for mowing and meadowlands is permitted. An alternative is the use of such land for the growing of energy crops.

[5] Degrees of soil contamination are described in the text.

III° – Moderately contaminated soil – Plants grown on such soils are exposed to contamination by heavy metals. The growing of cereals, root vegetables, and forage is recommended, where they should be periodically monitored for metal content in the consumable and fodder parts of the plant. Also allowed is the growing of industrial and energy plants and for the production of seed material. Groundwater may be at risk of pollution by heavy metals, especially cadmium, zinc, and nickel. In the case of meadowlands, they should be monitored for the intake of heavy metals by animals.

IV° – Strongly contaminated soil – It is especially light soils that should be excluded from agricultural production. It is recommended that better types of soils (heavier) should be used for the growing of industrial crops (hemp and linen), wicker, cereals and grasses (sowing material), potatoes, and cereals earmarked for the production of alcohol, rapeseed for technical oils, tree and shrub seedlings, etc. Green use should be restricted. Recultivation efforts are recommended, particularly liming and the introduction of organic substances. Such soils may be used for growing bio–energy crops.

V° – Highly contaminated soil – Such soils should be completely excluded from agricultural production and forested due to the travel of pollutants with soil particulate matter. The growing of selected varieties of energy plants with the most effective phytoremediation properties may significantly limit the transfer of heavy metals to successive food levels and be an alternative to forestation.

Rural areas are characterized by significant variety in terms of level of economic development, investment level, technical and social infrastructure development, as well as the affluence of the local government and the living conditions of the inhabitants. Changes taking place in the function of rural areas are a challenge for the nation's agricultural and regional policy. Plant production for consumption should be located on the best soils, free of contaminants, while arable land with limited agricultural usefulness should be designated for the growing of optimally selected energy plants. To a great extent this requires a change in the manner of thinking of farmers and the participation of the local authorities in raising the awareness of inhabitants and conducting a campaign promoting the development of alternate energy sources. The relevant field units of the Voivodeship of Łódź that are responsible for oversight and the sanitary state of the soil should develop a constructive strategy that will work against anthropogenic pollution. These services should especially pay attention to the application of safe and modern technologies that have a favorable impact on protection of the natural environment.

4. Conclusion

Phytoremediation using energy plants is a cost effective, promising, and dynamically developing technology for cleaning the environment, especially large areas for which currently known mechanical methods for removing heavy metals is loss–generating and unjustified. The phytoremediation properties of energy plants make possible the use of poor and degraded soils for agricultural development to return a part of such soil to the sustainable agricultural environment. Phytoextraction is the only economically viable method for removing valuable trace elements from the soil, including gold, cobalt, and platinum. A major share of poor and polluted soils in the country require the immediate development of a constructive strategy for application of phytoremediation and its economic analysis in reinstating a sustainable environment.

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Streszczenie

EKONOMICZNE I GLEBOWE UWARUNKOWANIA ZASTOSOWANIA FITOREMEDIACJI W PRZYWRACANIU ZRÓWNOWAŻONEGO ROZWOJU ŚRODOWISKA

Celem niniejszego artykułu jest przedstawienie priorytetowych zagadnień i powiązań, dotyczących ekonomicznych i glebowych uwarunkowań zastosowania technologii fitoremediacji w przywracaniu zrównoważonego rozwoju środowiska. Analizie poddano zasadność stosowania fitoremediacji w przywracaniu zrównoważonego środowiska jako metody alternatywnej do kosztownej rekultywacji terenów w celu usuwania zanieczyszczeń, które jest niewykonalne do przeprowadzenia na dużych areałach. Wykazano opłacalność stosowania fitoremediacji w odzyskiwaniu pierwiastków śladowych z gleby w procesie phytominingu.

Przeanalizowano jakość gleb występujących w województwie łódzkim w aspekcie potencjalnego zastosowania metody fitoremediacji z uwzględnieniem podziału metali ciężkich zawartych w glebach uwzględniający ich pochodzenie oraz właściwości. Przedstawiono klasy czystości gleb i wyznaczone w nich graniczne zawartości metali ciężkich.

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Sustainable Energy Crop Production in Poland: Perspectives

Abstract

In the context of achieving the targets of the energy economy, Poland's demand for bioenergy is stimulated by several factors, including the biomass potential of agricultural cultivation. The objective of this article is to indicate perspectives for the sustainable production of energy crops in Poland through the production of total biomass as the main renewable source of energy utilized in the countries of Europe and supported by Directive 2009/28/EC of the European Parliament and of the Council of April 23, 2009 on the Promotion of the Use of Energy from Renewable Sources, currently in force. The most important reasons for promoting the production of plant biomass for energy purposes is the desire to work against climate change and reduce the emission of greenhouse gasses. This article indicates the significant role of Life Cycle Assessment (LCA) in biofuels and their production. Note is also taken of agro–climatic and soil conditions for the production of biomass in Poland as well as the economic aspects using the Agricultural Production Space Valuation Ratio (APSVR).

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1. Introduction

With the growth of an awareness of threats flowing from overexploitation and the ignoring of global climate change, governments, companies, and the public have started to work together to implement the concept of sustainable development. Scientific research institutes have gained access to funds for the development of new green technologies, while companies have started to use them happily, simultaneously creating their own innovative solutions. Green business is not limited exclusively to increasing the share of renewable energy in total production, which was set out centrally in the member states of the European Union, but also influences the types of activities undertaken by companies in just about all branches of the economy. Environmentally–friendly management allows countries and their citizens to draw benefits in the form of healthier, less energy–using cities, clean air, water, and soil, and better management of space and waste. Factors such as climate change, globalization, and urbanization put new challenges before Europe and the World. Responsible management of energy, water, and waste has become a necessity. In order to guarantee an appropriate living standard and generate profits in the face of ongoing climate changes, businesses must make changes in existing products and technologies as well as create and develop completely new technologies. Legal regulations and preferential treatment for green technologies as well as growing prices and shrinking stocks of conventional sources of energy and raw materials stimulate the development of environmentally–friendly markets, the generation and storage of energy, energy efficiency, raw material efficiency, waste management and recycling, sustainable water use and sustainable transportation. It is possible that energy generated using renewable sources may replace the energy potential produced using conventional raw materials and, in the long run, even atomic energy, assuming no new revolutionary changes occur in this field (such as cold fusion, for example). It is projected that the development of biofuels of the second (produced using lignocellulosic biomass) and third (produced using algae) generation as well as progress in photovoltaic and hydrogen technologies will completely transform the face of the automobile industry and, in a somewhat more distant future, the aviation industry. However, before this takes place, a lot of attention will continue to be concentrated on the improvement of technologies based on fossil fuels, especially in the realm of improved turbine and engine efficiency as well as reductions in GHGs other than CO_2 in the face of the present energy situation. In many countries, this process will most probably slow the dissemination of renewable energy above levels as required by legislation. It is for this reason that the development of energy using renewable sources will be influenced by policies on the state level as well as the involvement of international organizations. Creation of favorable conditions and rewarding entities investing in green technologies is stated first by companies from all sectors of the economy as a factor stimulating progress in this field (Henzelmann et al., 2011, pp. 7–25).

2. Biomass production

Biomass is the source of 10% of world energy consumption. The remaining 90% produced using fossil fuels (80%), hydropower (2%), atomic energy (6%), and solar energy (2%). The share of energy derived from biomass varies significantly depending on the part of the world. OECD nations account for a mere 3.9%. The figure for developing nations is 18.8%, while the sub–Saharan region of Africa accounts for 61.5% (Goldemberg 2011, p. 3).

Biomass encompasses an extremely broad scope of raw materials such as forest products (wood, logging residues, trees, shrubs and wood residues, sawdust, bark, etc.), biorenewable wastes (agricultural wastes, crop residues, mill wood wastes, urban wood wastes, urban organic wastes), energy crops (short rotation woody crops, herbaceous woody crops, grasses, starch crops, sugar crops, forage crops, oilseed crops), aquatic plants (algae, water weed, water hyacinth, reed and rushes), food crops (grains, oil crops), sugar crops (sugar cane, sugar beets, molasses sorghum), landfill, industrial organic wastes, algae, kelps, lichens, and mosses (Demirbas 2009, pp. 55–56).

Growth in the share of energy derived from biomass is relatively slow because there are still a large number of unknowns. Firstly, there is the problem of stability of supplies and levels of biomass reserves are insufficient to satisfy energy and heat production needs. Secondly, it is not known if the utilization of biomass is economically viable at current and future fossil fuel prices, especially assuming no system of subsidies. The present rate of growth of biomass share is insufficient to satisfy requirements set for the year 2020. Achieving a level of energy and heat utilization using biomass of 1,650 TWh annum^{-1} as established by the European Commission necessitates the delivery of biomass with a primary energy of between 1,850 and 3,400 TWh, depending on method of use. Such a level may prove very difficult at this time due to an insufficiently attractive biomass value chain in the case of most countries and methods of utilization. Uncertainty on the part of companies, forest owners, and farmers with respect to the energy use of biomass in the future is hampering long–term investments. Without intensified action a paradoxical situation may emerge in which in spite of a lowering of biomass production costs, its price will go up as a result of growing demand caused by the costs of CO_2 emissions and green certificates as well as insufficient supply. This may have a negative impact on the paper industry. Thus, what is necessary is decided and quick action if the European Union wants to take advantage of its internal biomass production potential. In spite of the fact that biomass is the main renewable energy source utilized in Europe (Table No. 1) and the countries of the European Union consume 41.5% of the world's energy from renewable sources (Table No. 2), there is still a significant shortfall to achieving set targets and especially the whole of its bioenergy potential.

The most significant reason for promoting the production of biomass for energy purposes is the desire to work against climate change. A popular argument for absolutely vital action provides a slogan that says that production and energy utilizing biomass is neutral in terms of carbon dioxide emissions. This supposition is not completely true as the production of energy plants is tied with the direct and indirect emission of greenhouse gasses. This involves the burning of fuels during cultivation and transportation as well as in the production of fertilizer and plant protection chemicals. Additionally, the use of nitrogen fertilizer and post–harvest remnants release certain amounts of nitrous oxide whose role in creating a global warming potential (GWP) is 298 time greater than that of carbon dioxide. According to Crutzen et al. (2008), the production of first generation liquid fuels using cereals and rape may result in climate warming. It is only bioethanol made of sugar cane that may bring about a decrease in the greenhouse effect.

The basic assumptions behind the certification system for sustainability of the first generation biomass production chain are tied with the transposition of the guidelines of the European Commission as contained in the directives of the European Parliament and Council. Of significance is the fact that Directive 2009/28/EC encumbers fuel suppliers with an obligation to reduce the emission of greenhouse gasses derived from the fuel over its entire life cycle. This means including its production in the refinery, during transportation, and subsequently during combustion in engines. In its turn, Directive 2009/30/EC of April 23, 2009 (modifying Directive 98/70/EC) applies to gasoline and Diesel fuel specifications and also introduces mechanism for monitoring and limiting the emission of greenhouse gasses. Application of life cycle assessment (LCA) for biofuels and their production allows for a fuller assessment of their environmental impact. Analysis of their life cycle (LCA) is an evaluation method encompassing the complete production and product use chain. In the case of biofuels it encompasses the production of reproductive material, the establishing of plantations, cultivation, harvesting, transportation, the building and use of systems for processing biomass, all the way to the management of wastes generated in the production of energy. Pursuant to the PN–EN ISO 14040 standard, life cycle assessment may be used to:

- Identify environmental threats occurring in the technological line of the given products, during various stages of its life cycle,
- Select significant indicators for assessing the effects of activities on the environment, including measurement techniques,
- Undertake decisions in industry, government organizations, and nongovernmental organizations (strategies, priorities, and process design, inclusive of proposed changes in this regard), and
- Undertake marketing actions in the area of environmental assessment, product environmental declarations, descriptions of the processes that are the subject of licenses, etc., where due to the complexity of questions of environmental management, their solutions usually requires the collaboration of interdisciplinary teams, where all system components—economic, legal, technical, and related to the natural environment—must be taken into account in order to develop the proper action strategy.

Zah et al. (2007) applied a modified LCA method in their wide–ranging research into biofuel. They state that most biofuels are characterized by a more negative impact on the environment than gasoline. Only ethanol made of sugar cane and sugar beets, biodiesel made using spent oil, and biofuels made of wood had a more favorable impact on the environment than gasoline. The results of that analysis stress the importance of the development of second generation biofuels made of lignocellulosic biomass (Faber 2008).

Table 1. Primary production of renewable energy: 1999 and 2009

	Primary production (1,000 toe[1])		Share of total, 2009 (%)				
	1999	2009	Solar energy	Biomass and waste	Geothermal energy	Hydropower energy	Wind energy
EU—27	92,674	148,435	1.7	67.7	3.9	19.0	7.7
Euro area	62,261	104,794	2.2	64.4	5.4	18.7	9.2
Belgium	498	1,661	1.5	91.4	0.2	1.7	5.2
Bulgaria	665	1,129	—	68.9	2.9	26.4	1.8
Czech Republic	1,409	2,593	0.5	90.5	—	8.1	1.0
Denmark	1,619	2,754	0.5	78.0	0.4	0.1	21.0
Germany	8,069	27,692	3.5	77.0	1.7	5.8	12.0
Estonia	526	864	—	97.7	—	0.3	2.0

[1] Tons of oil equivalent

Ireland	222	614	0.7	45.3	—	12.7	41.4
Greece	1,419	1,804	10.4	51.2	1.2	25.1	12.1
Spain	6,031	11,905	5.7	47.9	0.1	19.0	27.3
France	16,528	19,567	0.3	70.2	0.6	25.1	3.5
Italy	9,401	14,746	1.0	34.0	32.6	28.7	3.8
Cyprus	44	75	77.3	21.3	—	—	—
Latvia	1,571	2,089	—	85.6	—	14.2	0.2
Lithuania	656	992	—	94.5	0.5	3.6	1.4
Luxembourg	35	80	2.5	80.0	—	11.3	6.3
Hungary	843	1,851	0.3	92.0	5.2	1.1	1.5
Malta	0	0	:	:	:	—	—
Netherlands	1,210	2,768	0.9	84.4	0.1	0.3	14.2
Austria	6,675	8,352	1.5	54.6	0.4	41.5	2.0
Poland	3,757	6,031	0.0	94.8	0.2	3.4	1.5
Portugal	3,342	4,747	1.1	66.4	3.7	15.0	13.7
Romania	4,400	5,275	—	74.2	0.5	25.3	0.0
Slovenia	551	863	—	53.1	—	46.9	—
Slovakia	458	1,223	—	68.5	0.7	30.7	0.1
Finland	7,256	7,833	0.0	85.8	—	13.9	0.3
Sweden	13,359	15,819	0.1	62.8	—	35.8	1.4
United Kingdom	2,133	5,107	1.4	74.1	0.0	8.9	15.7
Norway	11,872	12,116	—	9.7	—	89.6	0.7
Switzerland	4,693	4,760	0.9	30.1	4.4	64.5	0.0
Croatia	900	1,030	0.5	42.6	0.3	56.2	0.5
Turkey	10,701	9,909	4.3	46.8	16.4	31.2	1.3

Source: Eurostat.

Table 2. Consumption of renewable energy[2] in member states of the European Union and the United States (2001–2011)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Change 2011 over 2010 %	2011 share of total world production %
	million tonnes of oil equivalent[3]												
Austria	0,4	0,4	0,5	0,7	0,9	1,2	1,4	1,4	1,4	1,5	1,6	8,20	0,80
Belgium	0,4	0,4	0,4	0,5	0,6	0,8	0,9	1,1	1,5	1,6	2,1	27	1,10
Bulgaria	-	-	-	*	*	*	*	*	0,1	0,2	0,3	61,8	0,10
Czech Republic	0,1	0,1	0,1	0,2	0,2	0,2	0,3	0,4	0,5	0,7	1,1	60,90	0,60
Denmark	1,3	1,6	1,8	2,2	2,2	2,1	2,4	2,3	2,3	2,8	3,4	21,40	1,80
Finland	1,9	2	2,1	2,4	2,2	2,5	2,3	2,4	2	2,5	2,6	1,70	1,30
France	0,7	0,8	0,9	1	1,1	1,4	1,9	2,3	2,8	3 ,4	4,3	26,90	2,20
Germany	3,6	5	6,2	8,2	9,6	11,7	15,2	16,4	16,9	18,9	23,2	22,90	11,90
Greece	0,2	0,2	0,3	0,3	0,3	0,4	0,5	0,6	0,6	0,7	0,9	29,70	0,50
Hungary	*	*	*	0,2	0,4	0,3	0,3	0,5	0,6	0,6	0,7	3,40	0,30
Ireland	0,1	0,1	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,7	1,1	51,30	0,50
Italy	1,9	2,2	2,6	2,9	3,1	3,5	3,8	4,1	4,6	5,8	7,7	32,10	4,00
Lithuania	*	*	*	*	*	*	*	*	0,1	0,1	0,1	67,10	0,10
Netherlands	0,7	0,9	0,9	1,2	1,7	1,8	1,7	2,1	2,4	2,5	2,7	8,40	1,40
Poland	0,1	0,1	0,1	0,2	0,4	0,5	0,7	1	1,4	1,8	2,2	26,90	1,20
Portugal	0,4	0,5	0,5	0,6	0,8	1,1	1,4	1,8	2,3	2,8	2,8	2,10	1,50
Romania	-	*	*	*	*	*	*	*	*	0,1	0,2	226,50	0,10
Slovakia	*	*	*	*	*	*	0,1	0,1	0,1	0,1	0,1	1,80	0,10
Spain	2	2,9	3,6	4,4	5,6	6,2	7,2	8,7	10,7	12,5	12,7	1,50	6,50
Sweden	1	1,1	1,3	2	2,1	2,3	2,7	3	3,1	3,5	4,1	16,80	2,10
UK	1,2	1,4	1,7	2,1	2,7	3,1	3,3	3,7	4,5	5	6,6	32,30	3,40
EU	16,2	19,8	23,2	29,2	34,3	39,5	46,7	52,7	58,8	68,1	80,9	18,90	41,50
USA	16,8	18,7	18,8	19,6	20,6	22,7	24,7	29,5	33,6	38,9	45,3	16,40	23,20

Source: based on BP Statistical Review of World Energy, June 2012, bp.com/statisticalreview, p. 38.

[2] Based on gross generation from renewable sources, including wind, geothermal, solar, biomass, and waste, and not accounting for cross–border electricity supply.

[3] Converted on the basis of thermal equivalence assuming 38% conversion efficiency in a modern thermal power station.

* Less than 0,05.

3. Biomass production climate and soil conditions in Poland

A breakthrough took place over recent years in the development of information technology and its application in analyzing phenomena of spatial character. Methods and instruments created or adapted in Poland as a result of work on the Integrated Spatial Information System for Agricultural Production (ISISAP) may be operationally used to assess regional differentiation in agricultural production conditions, simultaneously replacing the traditional descriptive expert reports with more accurate quantitative analysis based on continuous monitoring as well as analysis of updated databases and continuously improved methods for modeling and making projections (Krasowicz and Kopiński 2009).

Each year, only a small part of devastated and degraded areas of Poland are subject to efforts aimed at their recultivation and redevelopment for agricultural functions. For all practical purposes, such actions are not undertaken in the Voivodeship of Łódź. Areas requiring recultivation are forested. Bearing in mind the fact that a total of 2,935 ha of agricultural land (192 ha in the Voivodeship of Łódź) as well as 551 ha of forests (215 ha in the Voivodeship of Łódź) were released for mining operations and housing estate sites in Poland in the year 2010, the intensification of actions aimed at returning degraded areas to agriculture is justified. Analysis of the soil growing quality grade structure of land withdrawn in 2010 shows that most is classified Grade IV (789 ha), which is appropriate for energy crops, and Grades I–III (922 ha), which is for food production. Only 111 ha were classified as Grades V and VI, where agricultural use is very limited. Also worth noting is the systematic decrease of fallow and set–aside land in Poland from approximately 11.9% of total arable land in 2000 to 3.8% in 2008. The year 2009 saw a slight increase in these areas to 4.1%. The largest percentage share of fallow and set–aside land belongs to the public sector. In the year 2009 it amounted to 65,500 ha (CSO, 2011a). According to the Central Statistical Office (GUS), Poland has seen a continuous tendency of a decrease in arable land area and an increase in forest areas since 1938. Over the years 1990–2009 this was -7% and +1.7%, respectively, of Poland's surface area. In 2011 the area of arable land decreased by 48,000 ha as compared with the year 2010, while the forest use area increased by 29,000 ha.

The Agricultural Production Space Valuation Ratio may be used as a measure of the production potential of a habitat. Weights assigned in assessing individual factors are mirrored in their rank in shaping harvest levels. Soil conditions are of greatest importance in valuating agricultural production space (approximately 70% of observable harvest variability – 18–95 points). The influence of the remaining factors is significantly lower and accounts for approximately 30% (Igras and Lipiński 2006). The share of the climate factor (agro–climate) is in the 1–15 point range. The influence of water conditions rates 1–5 points, while landform can receive 0.1–5 points. Variations in the natural production potential on a national scale stems from spatial soil differentiation, landform, precipitation, and temperature. The value of the valuation indicator is contained in the range from 31 points for habitants least useful for agriculture to 120 points for the best habitats with optimum conditions for plant growth. The average Agricultural Production Space Valuation Ratio for Poland amounts to 66.6 points (Table No. 3). The greatest restrictions in the development of plant production occur in areas with an indicator value of less than 52 points. The largest concentrations of land of little usefulness for agriculture are found in the Podlaskie (the lowest value for Poland at 55.0 points), Mazowieckie, and Pomorskie voivodeships (Igras and Lipiński 2006).

Table 3. Partial and overall agricultural production space valuation ratio by voivodeship

Voivoidships	Valuation indicator				Total Agricultural Production Space Valuation Ratio
	Quality and usefulness of agricultural soils	Agricultural climate	Landform	Water conditions	
Dolnośląskie	56.9	10.4	3.8	3.8	74.9
Kujawsko–pomorskie	54.4	9.2	4.0	3.4	71.0
Lubelskie	55.8	10.6	4.0	3.8	74.1
Lubuskie	43.6	11.6	4.3	2.7	62.3
Łódzkie	43.2	11.5	4.4	2.8	61.9
Małopolskie	53.6	9.3	2.4	4.0	69.3
Mazowieckie	43.1	9.7	4.1	3.0	59.9
Opolskie	60.5	13.4	4.1	3.6	81.6
Podkarpackie	52.7	10.7	3.0	4.0	70.4
Podlaskie	41.0	7.5	3.7	2.8	55.0
Pomorskie	50.6	8.5	3.7	3.4	66.2
Śląskie	46.8	11.2	3.6	2.6	64.2
Świętokrzyskie	52.2	10.6	3.1	3.5	69.3
Warmińsko–mazurskie	51.1	8.1	3.4	3.4	66.0
Wielkopolskie	46.4	11.2	4.4	2.8	64.8
Zachodniopomorskie	50.0	9.8	4.0	3.6	67.5
Poland	49.5	9.9	3.9	3.3	66.6

Source: based on Igras and Lipiński, 2006.

4. Plant Cultivation Conditions in Poland

Natural conditions for plant production in Poland are worse in comparison with other European countries (Kukula and Igras 2004). The reason for this is the dominance of light soils of low natural fertility, insufficient precipitation, and a relatively short growing season.

4.1.Soil

The share of very light and light soils in Poland is approximately 60%. Most of the soils are strongly or moderately acidic and demonstrate a low content of basic nutrient components. Changes in plant production structure have a significant impact on soil fertility, which determines both the volume and intensity of agricultural production in a direct way. Among aspects defining the fertility of the soil, the most important are acidity, organic matter content, nitrogen mineral form, and abundance of macro– and micro–elements (Igras and Lipiński 2006).

4.2. Soil Acidity (pH)

From an agricultural point of view, it is the negative effects of the acidifying of the soil that are extremely important. A low pH lowers the assimilability of nutrient components, especially phosphorus, magnesium, and molybdenum. At the same time, it increases the mobility of components such as aluminum and heavy metals. The accumulation of heavy metals in the soil, especially cadmium and lead, may lead to their excessive concentration in plants. A high content of these metals disqualifies plants for consumption. The acidity structure of soils in Poland is presented in Table No. 4. The worsening of the acidity of the soil is a phenomenon that is progressing as a result of the insufficient application of CaO in cultivation (Igras and Lipiński 2006). The use of lime fertilizers in Poland fell from approximately 1,693,900 tons (95.1 kg ha^{-1} UR) in the year 1999 to 591,400 tons (38.1 kg.1 kg ha^{-1} UR) in the year 2010. The lowest use per hectare of agricultural land occurs in the Świętokrzyskie, Małopolskie, Podkarpackie, and Podlaskie voivodeships. The highest use of 102.8 kg ha^{-1} is found in the Voivodeship of Opole (CSO, 2011b). The solving of the problem of soil acidification and the improvement of its acidity should be a priority of state policy in the area of agriculture.

Table 4. Structure of soil acidity in Poland in 2006–2010

Voivoidships	Soil acidity (%)				
	Very acidic pH < 4.5	Acidic pH 4.6 – 5.5	Slightly acidic pH 5.6 – 6.5	Neutral pH 6.6 – 7.2	Alkaline pH > 7.2
Poland	18	29	30	15	8
Dolnośląskie	12	28	38	15	7
Kujawsko-pomorskie	8	20	30	25	17
Lubelskie	22	28	23	15	12
Lubuskie	13	35	36	11	5
Łódzkie	33	34	21	9	3
Małopolskie	26	28	22	15	9
Mazowieckie	30	32	22	12	4
Opolskie	5	19	50	21	5
Podkarpackie	33	32	21	11	3
Podlaskie	26	34	23	13	4
Pomorskie	15	37	30	14	4
Śląskie	11	25	40	18	6
Świętokrzyskie	20	22	22	19	17
Warmińsko-mazurskie	16	33	30	17	4
Wielkopolskie	15	26	33	15	11
Zachodniopomorskie	14	31	31	15	9

Source: based on *Environment*, Dariusz Bochenek (Editor), CSO, Regional and Environmental Surveys Division, Warsaw, 2011.

4.3. Nitrogen

The mineral nitrogen content in the soil is one of the defining elements of soil fertility. Its quantity is dependent on many environmental factors such as the type, forecrop, species of cultivated plant, and applied dosages of nitrogen and natural fertilizers as well as the granulometric soil composition. The use of nitrogen fertilizer increased from 48.4 to 66.3 kg ha^{-1} over the years 1999–2010 (CSO, 2011b). Analysis of the regional differentiation of mineral nitrogen content in Polish soils shows that the lowest content is characteristic of the soils of eastern and southeastern Poland, but primarily the soils of the Pomorskie and Warmińsko–Mazurskie voivodeships. On the other hand, the soils of the Śląskie and Dolnośląskie voivodeships have the greatest abundance of this component

(Igras and Lipiński 2006). Permanent plantations of energy crops are characterized by significantly greater efficiency in nitrogen utilization as compared with traditional crops. The increased efficiency of nitrogen uptake decreases the leaching away of nitrates. Following vegetation, many species of energy plants withdrawn large quantities of micro– and macro–elements into their roots. Thanks to this they are not removed with the biomass harvest (Faber 2008).

4.4. Organic Matter

The quantity of organic matter in the soil is a basic indicator of its quality. It defines its physical and chemical properties (sorption and buffering capacity) and the processes of biological change that is important to the functioning of the habitat (biological activity). High humus content in the soil is a factor stabilizing its structure, decreasing susceptibility to compacting as well as degradation resulting from water and wind erosion. The maintenance of soil humus resources is also important from the point of view of the sequestering of carbon dioxide from the atmosphere. Intensive use of the soil by monoculture destroys the soil structure, and leads to excessive aeration of habitats as well as the mineralization of humus, thus freeing large amounts of carbon dioxide into the atmosphere. CO_2 emissions from the soil are a significant part of the total balance of emissions from various sectors of the economy. In the cultivation of energy crops, a certain quantity of carbon assimilated by plants finds its way into the soil with falling leaves and dying roots. Over 80% of this quantity is transformed into CO_2 as a part of the soil respiration process, while the remainder is sequestered as a result of gradual transformation into humus. Growth in the carbon content of the soils of such plantations acts to indirectly improve the texture, water capacity, and fertility of the soil. This process is dependent on climate conditions, the granulometric makeup of the soil, and its initial humus content (Jug et al. 1999). The quantity of sequestered carbon in the soil in the case of energy plant cultivations is of importance with respect to the overall carbon balance and therefore the greenhouse gas emission balance. It is assumed in LCA analyses that the emission of greenhouse gases in the cultivation of willow and miscanthus is significantly lower than in the case of cultivation of rape, green areas, and wheat (Clair et al. 2008; Faber 2008). The natural variety in humus content in soils is determined by factors including granularity, location in the terrain, and water relations. Among anthropogenic factors, the organic matter content of the soil is most influenced by land use (i.e. agriculture, meadow, forest), intensity of cultivation, selection of cultivated plants, and level of natural and organic fertilization. Changes in the content of organic matter in soils are coupled with two opposed processes—mineralization and deposition. The process of mineralization leads to a lowering of organic content in the soil. The process of deposition results in an increase in humus content due to the continuous adding of organic matter from sources such as post–harvest remnants and natural and organic fertilization (Stuczyński et al. 2007). Loss of humus is an important indicator of worsening habitat conditions and soil fertility. Growth in the area of agricultural land used exclusively for plant production in farms lacking any animal husbandry, thus deprived of the natural and organic fertilization that are significant elements shaping soil humus resources, has been taking place in certain regions of the country. In the case of perennial energy plant plantations, sewage sludge may serve as a source of organic matter fertilization, which is simultaneously a way for its utilization. The average content of soil humus in Poland is 2.2%. In line with international criteria, humus content below 3.5% is considered a symptom of desertification. Taking such an approach, 89% of the surface area of Poland's agriculturally useable soils should be classed as soils of low organic matter content and be considered threatened by drought. Obviously, this is a consequence of the specifics of Polish soils. They have a large share of soils formed from sands and light soils of low water capacity, which in a natural way determines conditions of humus accumulation. Studies indicate the existence of a strong trend of humus content loss, mainly in soils originally rich in organic matter, linked with changes in soil water relations, more intensive use, and drainage (Stuczyński et al. 2007).

4.5. Soil Compaction

The increase in mechanized work in the field during sowing and harvesting agricultural products often leads to excessive compaction of the soil in both the tilled layer and the subsoil, especially in highly developed countries. Heavy machines and tractors moving over the fields cause the excessive compaction of soil layers, even up to a depth of > 0.9 m. Excessive compaction impedes penetration of the soil by the roots of cultivated plants that, subject to such unfavorable conditions, have limited access to water and nutrients. Moreover, pore size decreases, the percentage of pore surface area filled with water at field capacity increases, and the temperature of the soil falls. This influences the activity of soil organisms by decreasing the indicator of organic substance decomposition and the freeing of nutrient components for plants. Soil compaction results in lower infiltration, which results in an increase in surface off–flow and the creation of stagnant ponds without drainage. The susceptibility of soils to compaction is dependent on soil water content at the moment of the operation. Soil containing less water is more resistant to compaction than soil that is humid or wet. The soils in Poland demonstrate significant diversity in susceptibility to compression, which is due to differences in granulometric makeup and organic matter content. The total soil surface area highly vulnerable to compaction resulting from improper cultivation techniques due to equipment with excessive loads and subject to conditions of excessive moisture amounts to approximately 2.6 million ha, which is approximately 15% of agricultural land use. The soil cover of the Dolnośląskie (41.2%), Małopolskie (40.5%), Opolskie (34%), and Podkarpackie (33.6%) voivodeships is characterized by a large share of soils susceptible to compaction (Stuczyński et al. 2007). Excessively moist cohesive alluvial soils as found in river valleys provide particularly unfavorable conditions for cultivation during periods of cultivation work. The effects of compaction on these soils is long–term and difficult to reverse.

4.6. Soil Erosion

Water erosion is a significant threat to soil quality. The level of threat of soil erosion through surface water is dependent on the slope of the land, susceptibility of the soil to washing away, and the level of annual precipitation. In order to decrease the still rather high current threat of erosion by surface water it is necessary to apply erosion–preventing land improvements in areas where it is present. This includes the transformation of agricultural land use into protective land use. This applies to over 2.2 million ha, where approximately 500,000 ha are very strongly threatened by water erosion. Assuming the continued withdrawing of areas from arable land in favor of forestation, tree planting, and other agricultural uses (energy crop plantation, orchards, and permanent green areas) with soil–protective functions, a decrease in the range and intensiveness of both water and wind erosion should be expected (Stuczyński et al. 2007). In the case of Poland, 27.6% of agriculturally used soils are threatened by wind erosion, where the figure for water erosion is 28.5%. This factor is worth considering in selecting species of perennial energy plants. The common osier (*Salix viminalis*), switchgrass (*Panicum virgatum*), black locust (*Robinia pseudoacacia*), and multiflora rose (*Rosa multiflora*) are species used in fighting erosion processes. They bring about a decrease in the susceptibility of the soil to washing away by reinforcing it with their root systems, absorbing the energy of raindrops, holding a part of the precipitation in above–grade organs, and decreasing the velocity of water flow by increasing the roughness of the land surface (Węgorek 2008). Soil drought and the global trend for increased average monthly temperatures may lead to a drying of the soil below its average natural moisture content. As a consequence, this may significantly increase the range and intensity of water erosion on arable land (Stuczyński et al. 2007).

4.7. The Occurrence of Trace Elements

Information regarding the state of agricultural use soil pollution by heavy metals in Poland is based on the results of broad studies on the chemistry of Polish soils conducted over the years 1992–1997. Over 99% of the soil in Poland is found to contain copper, nickel, and lead on a natural background level (0 degree) or at a slightly higher level (I degree). In line with approved criteria, such soils are considered uncontaminated. With respect to cadmium and zinc, this share amounts to over 98%. A total of 21.5% of the agricultural soil of the Śląskie Voivodeship is contaminated with cadmium in the II to V degree range, where 4% are soils that are strongly or very strongly contaminated. There is also lead and zinc pollution. This fact is tied with the operation of zinc and lead ore mining and processing (emission of particulate matter) and the occurrence of ore–bearing rock outcrops on the surface. Higher metal content on a level exceeding boundary values also occurs locally in the soils of other regions historically burdened with the effects of metal ore mining and processing (Głogów, Lubin, Chrzanów, Olkusz). On the basis of the above data as well as legal regulations currently in effect in Poland, it may be stated that over 99% of the surface area of agricultural land, on a national scale, meets criteria for metal content as required for agricultural soils. In many areas, in spite of a low level of trace metal content in the soil, an exceeding of allowable amounts has been noted in plants. Cadmium accumulation in plants, which is most frequent, is primarily linked to the strong acidification of the soil, which is responsible for its high bio–accessibility. This indicates a need to take into account soil properties in developing criteria for assessing metal pollution (Stuczyński et al. 2007).

4.8. Agro–Climatic Conditions

To a great extent, the worsening of the climatic water balance in the growing season and the increasingly frequent occurrence of deficits of precipitation shape the production potential of habitats. Global warming is causing not only an increase in heat resources, which in Poland's climate zone is one of the positive effects of climate change, but also increases the variability of weather changes over successive years. It is subject to such conditions that possibilities of cultivating other thermophilous plants such as miscanthus and switchgrass increase. Analyses of harvest weather indexes (the impact of meteorological elements on plant harvests achieved in Poland) confirm that the greater variability in the sequence of meteorological conditions over recent years may be the reason behind the occurrence of greater than to date losses in harvests due to the passage of unfavorable weather. A less optimistic scenario of climate change in which the increase in temperature is not accompanied by an increase in atmospheric precipitation is being observed in Poland. This situation shall have a negative effect on the water balance. There will be a further worsening of hydrological conditions for agriculture in those areas of Poland that have had the lowest water balance. This necessitates the undertaking of action aimed at adapting agriculture to present and future climate conditions (Stuczyński et al., 2007). Multi–year cultivation of energy plants usually produces greater volumes of biomass than the growing of traditionally cultivated plants. It is for this reason that they have greater water demands. This signifies that subject to Polish conditions it will be necessary to grow such crops on land with a water table above 2 m. Under such conditions, plants can supplement insufficient precipitation by up–taking water from groundwater up to 200 mm. In the large–area sowing of such plants, the decreased supply of groundwater through precipitation should be taken into account. This premise forces the need to analyze in detail the hydrological effects of such plantings in the area of specific watersheds as well as the country as a whole. There is a negative climate water balance in most areas in Poland. As a result of the expected change in climate this situation may worsen from -10% for the optimistic scenario to -50% for the pessimistic one. Thus, what is necessary is serious consideration as to the locating of energy crop plantations. It should be expected that unfavorable water conditions will restrict the size of land area available for perennial energy plants in Poland to about one million ha (Faber 2008).

5. Conclusion

Biomass is the source of 10% of world energy consumption. Growth in the share of energy derived from biomass is relatively slow because there are still a large number of unknowns. There is the problem of stability of supplies and levels of biomass reserves are insufficient to satisfy energy and heat production needs. It is not known if the utilization of biomass is economically viable at current and future fossil fuel prices, especially assuming no system of subsidies. The most significant reason for promoting the production of biomass for energy purposes is the desire to work against climate change. Application of life cycle assessment (LCA) for biofuels and their production allows for a fuller assessment of their environmental impact. Natural conditions for plant production in Poland are worse in comparison with other European countries. Large scale cultivation of energetic plants is a sustainable method of use uncultivated and degraded soils. Environmentally–friendly management allows to draw additional benefits from energetic plants cultivation in the form of healthier, clean air, water, and soil, and better management of space and waste.

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Streszczenie

PERSPEKTYWA ZRÓWNOWAŻONEJ PRODUKCJI ROŚLIN ENERGETYCZNYCH W POLSCE

Zapotrzebowanie w Polsce na bioenergię w kontekście realizacji celów gospodarki energetycznej jest stymulowane przez szereg czynników, w tym potencjał biomasy pochodzący z upraw rolniczych. Celem artykułu jest wskazanie na perspektywę *zrównoważonej produkcji roślin energetycznych w Polsce poprzez produkcję całkowitej biomasy jako głównego odnawialnego źródła energii wykorzystywanego w krajach Europy, a wspieranego przez obecnie obowiązującą Dyrektywę Parlamentu Europejskiego i Rady 2009/28/WE z dnia 23 kwietnia 2009 r. w sprawie promowania stosowania energii ze źródeł odnawialnych (OŹE). Najistotniejszymi powodami promowania produkcji biomasy roślinnej na cele energetyczne jest chęć przeciwdziałania zmianom klimatycznym i redukcja emisji gazów cieplarnianych. W artykule wskazano na znaczną rolę analizy LCA (Life Cycle Assessment) dla biopaliw i ich produkcji. Zwrócono uwagę na warunki agroklimatyczne i glebowe uwarunkowania produkcji biomasy w Polsce oraz ekonomiczny aspekt jakim jest wskaźnik waloryzacji rolniczej przestrzeni produkcyjnej (WWRPP).*

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Biomass Production of Selected Energy Plants: Economic Analysis and Logistic Strategies

Abstract

The objective of this article is the conducting of an analysis of the production of selected energy plants that are already a basic source of agrobiomass in Poland. The analysis looks at environmental aspects and production conditions for biomass designated for energy for the Virginia mallow (Sida hermaphrodita), common osier (Salix viminalis), silver–grass (Miscanthus x giganteus), and switchgrass (Panicum virgatum). What is presented is an economic analysis of the production of selected energy plants, taking into account the costs of establishing plantations and their cost effectiveness. Moreover, logistic strategies for the delivery of biomass intended to secure continuous production of renewable energy as a part of sustainable development is signaled.

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1. Introduction

Energy efficiency is one of the central objectives for 2020. It is also key to achieving the long-term energy and climate goals and the most cost-effective way to reduce emissions, improve energy security and competitiveness and keep energy costs down. The action plan presented by the European Commission aims to reduce the insecurity of investors by evaluating the physical and economic availability of different biomass types, including wood and wood residues, waste and agricultural crops, and by determining priorities regarding the biomass types in use and ways of developing them, as well as by pointing out measures to be taken in order to enhance this. The action plan is also connected with consumer information campaigns about the benefits of biomass and bioenergy[1].

Second generation energy plants—perennial forage plants—are considered the future of bioenergy and are subject to intensive study for this reason. Compared with plants of the first generation—annual bearing fruits of the caryopsis type—they produce more energy at significantly less input and have a more favorable GHG emission balance (Sanderson and Adler 2008). Among the many plants currently grown for energy biomass, the Virginia mallow, willow, miscanthus, and switchgrass have a good chance of development, assuming that their profitability will be higher than in the case of plants grown for consumption.

2. Environmental and economic conditions for agrobiomass production in the case of selected plants for energy biomass

2.1. Virginia Mallow

The Virginia mallow (*Sida hermaphrodita*) is a perennial plant originating from North America. The species has been known in Poland for over fifty years, which is when the Agricultural Academy of Lublin (presently the University of Life Sciences) launched studies on the possibility of its cultivation and use as fodder. It is a honey plant with a honey output of 110–315 kg ha^{-1} (Borkowska and Styk 2006).

[1] "DEVELOPMENT PLAN 2007−2013 FOR ENHANCING THE USE OF BIOMASS AND BIOENERGY",
http://ec.europa.eu/energy/res/biomass_action_plan/doc/nbap/information/estonia_en.pdf

Fresh unimproved seeds that are the source of the plants have a very low germination rate, which is on a level of 5–15%. The highest germination capacity is achieved after a one or two year period of storage (Antonowicz 2005). By using appropriate hydro–priming methods it is possible to increase it to over 50% (Grzesik et al. 2001). The Virginia mallow also reproduces through rooted cuttings planted at densities of 10,000–20,000 per hectare. Biomass harvests are made, depending on region, in the months of February, March, and April or at the time of first frosts in November and December. The moisture content of harvested biomass under natural conditions decreases from approximately 40% in November to approximately 20% in January. This allows its direct designation for palletizing (Borkowska and Styk 2006). A plantation may be effectively exploited for fifteen to twenty years (Antonowicz 2005).

The Virginia mallow, due to its low soil requirements, which are significantly lower than the common osier and *Miscanthus giganteus*, may be used to develop poorer soils, including all types of Grade V soils all the way up to sandy soils. This property of the mallow is especially significant in the case of use for the recultivation of degraded and polluted soils, where subject to unfavorable conditions it can produce 11 t d.m. ha^{-1} $annum^{-1}$. In practice, it may be cultivated in soils of Grade IVb and V poor Secale Complex with a water table at a depth of over two meters. In establishing plantations by way of sexual reproduction (using seeds), catchment area soils with tendencies for encrusting should not be used. Under favorable cultivation conditions, on Grade III soils, harvests may achieve 17 t d.m. ha^{-1} $annum^{-1}$. The harvesting of biomass should take place in the winter season (I–III) when the humidity is lower. The biomass may be compressed into bales or used in the production of briquettes and pellets.

The mallow is less sensitive to lack of mineral fertilizer when compared with the miscanthus. From an economic point of view, what is important is that the fertilizer needs of the mallow are very low in the year of the establishing of the plantation. Starting with the second year, recommended dosages of N–P–K per hectare are 90 kg N, 30–90 kg P_2O_5, and 80–150 kg K_2O. Nitrogen dosages amounting to 200 kg ha^{-1} do not have an impact on the number of shoots. However, increasing phosphorous fertilization from 39 to 53 kg ha^{-1} increases the number of shoots by an average of one per square meter, which give approximately 20,000 additional shoots per hectare (Borkowska et al. 2009). Studies have indicated that the use of treated sewage sludge, which is very inexpensive, increases biomass yields and facilitates its acquisition on very poor soils (Romanowska–Duda et al. 2009; Kacprzak et al. 2010). The mallow also demonstrates small sensitivity to soils with pH=6. This property is especially useful in the Voivodeship of Łódź, where the acidity of the soil is a universal problem. At the same time, the mallow takes up fewer nutrient elements from the soil than the willow or miscanthus (Łabętowicz and Stępień 2010). In the case of mallow harvests, only small amounts of fertilizer components are removed from the field because as the shoots dry, nutrients are moved to the rootstock or are retuned to the soil through falling leaves. Mallow biomass collected at the right time is characterized by low ash content and relatively few mineral components such as nitrogen, potassium, and chlorine—hence, the small outtake of fertilizer components with the harvest (Kuś and Matyka 2010).

The results of studies conducted to date indicate large lignocellulosic biomass harvests as compared with other energy plants. Moreover, heat of combustion is large—an average of 18.4 MJ kg^{-1}—and a lower heating value of 16.6 MJ kg^{-1} (Szyszlak et al. 2006; Borkowska and Styk 2006). The lower heating value and heat of combustion are dependent on the thickness of the mallow stem, which is strictly tied with planting density per 1 m^2. The highest heat of combustion and lower heating value amounting to 19.2 MJ kg^{-1} and 17.4 MJ kg^{-1}, respectively, were received from sprouts of a thickness in the 10 mm to 13 mm range (thickness achieved at a planting density of 23 sprouts per m^2) (Szyszlak et al. 2006). Biomass harvests with a moisture content of 20%–24% amount to 20 to 25 tons per ha^{-1} (Denisiuk 2006), with a theoretically assumed germination capacity of 100% and planting density amounting to 64,000 seeds per hectare, the biomass harvest may amount to 120 t ha^{-1}. Mallow stems on an appropriately dense plantation are easily crushed and compressed (Denisiuk 2006). Mallow harvests on land classified as clayey amount to 15–20 t d.m. ha^{-1} (Borkowska 2007), while in the case of difficult conditions using sewage sludge the amount to from 9 to 11 t d.m. ha^{-1} (Borkowska 2003). Similar or higher harvests as in the case of using sewage sludge are possible in the case of cultivation on light soils. Cultivation on soils classified as light silty–clay, depending on the dosage of nitrogen and phosphorous fertilizer, can amount to 6.71–9,54 t d.m. ha^{-1} in the second year and 10.29–11.75 t d.m. ha^{-1} in the third and fourth years. At the same time, it should be noted that with each year of the experiment, there were significant deficits of precipitation and droughts during June and July, periods of the greatest demand for water (Borkowska et al. 2009). Water shortages are also tied with the properties of light soils. Research conducted in the year 2005 on light soils gave a dry matter yield of 20.5 t d.m. ha^{-1} due to significant precipitation in July (Kuś and Matyka 2010). Appropriate irrigation systems should be considered in the event of cultivation on such soils. Studies conducted on various types of soils indicate that cultivation achieves full production potential in the third and fourth years. Virginia mallow harvests are decidedly dependent on planting density (Faber et al. 2007; Kuś and Matyka 2010). The mallow provides a low harvest when at a density of 10,000 per ha^{-1}, regardless of soil. In the case of sites with such a planting density on soils of Complexes 8 and 4, the harvest amounted to approximately 9 t ha^{-1} dry matter and was 20% lower than for light soils (Complex 5), where the planting density amounted to 20,000 ha^{-1}. However, good harvests were achieved when planting density was increased to 20,000 ha^{-1}. At the same time, harvests amounting to approximately 12 t d.m. ha^{-1} received on light soils should be considered interesting (Faber et al. 2007; Kuś and Matyka 2010).

The Virginia mallow was considered to be a plant free of agrophages (Borkowska and Styk 2006). However, according to the Poznań Institute for Plant Protection (IOR), approximately 30% of the plants on a plantation may be infested with spider mites and aphids. Bearing in mind the size of the mallow, their harmfulness is small and does not require the application of costly and environmentally undesirable plant protecting operations. Mallow plants were also infested with numerous omnivorous hemiptera such as the dock bug (*Coreus marginatus* L.) and the lygus bug (*Lygus* spp). The growing quantities of these insects suggests that in the case of multi–year plantations they, as well as butterfly caterpillars, may be a threat (Mrówczyński et al. 2007; Remlein–Starosta and Nijak 2007). The mallow is also susceptible to fungus infections of the *Fusarium*, *Sclerotinia sclerotiorum*, and *Botritis cinerea* type, causing fusariosis, *Sclerotinia sclerotiorum* mold, and noble rot (Grzesik et al. 2011).

2.2. Common osier

About 450 species of trees and shrubs throughout the world belong to the *Salix* genus. Among other things, willows are utilized to minimize the negative impact of Man on the ecosystem, including for the renovation, stabilization, and recultivation of disrupted areas, phytoremediation, the control and prevention of erosion, and the production of biomass (Kuzovkina and Quigley 2005). For economic reasons, in addition to the poplar and switchgrass, the willow is a promising energy plant for cultivation in United States regions with a moderate climate. The State University of New York developed a program for reproducing the willow whose effect is hybrids designated for the production of biomass and dendroremediation (Kopp et al. 2001). However, willow cultivation is of greatest importance in Sweden, the home of many varieties of willow that are also cultivated in Poland (Aronsson and Perttu 2001). A very useful feature in its cultivation is adaptation to growth at locations with very limited access to basic nutrient components. One of the reasons why this is possible is thanks to mycorrhizas, which guarantee additional sources of nutrients such as nitrogen and phosphorous. The colonization of disturbed areas by the willow marks a start, accelerating recultivation and bringing about increased biodiversity in such areas. Among changes that take place following the establishing of the willow in an area are the creation of humus, an improvement in soil structure and in the quantity of nutrient ingredient, shading, etc. The willow is also relatively resistant to salt (Highshoe 1988) and pollution, such as by heavy metals (cadmium, copper, zinc, lead) and radionuclide (cesium) (Kuzovkina and Quigley 2005). There are also reports of significant resistance to air pollution (Zvereva et al. 1997). Research into using the willow *Salix dasyclados*, that under defined conditions gives higher dry matter yields, are also underway (Tworkowski et al. 2010).

The common osier, with its favorable qualities as an energy crop, is a perennial plant with a plantation service life of fifteen–twenty years. The primary benefit of its cultivation is inexpensive and easy to independently prepare cuttings. The cultivation of only a single variety of willow on a plantation with a large area is a venture encumbered by significant risk. It is much safer to use several varieties, which should restrict the spreading of disease. In the case of cultivation for energy purposes, harvesting the willow once every three years is the best solution, as it is then that a bigger harvest per year is achieved, where additionally the wood has a higher energy value than in the case of an annual harvest. However, cultivation in a three–year cycle requires specialized and costly machines for the harvesting of biomass. The quick growth of biomass and its related intensive ion exchange between the roots and components of the polluted soil make this species particularly useful in its biological use in phytoremediation.

Both Swedish and English studies indicate that subject to moist condition the planting of willows at a density of 10,000–13,000 ha^{-1} is beneficial (Ericsson et al. 2009). Willows are harvested during the autumn–winter period when soils are usually very moist, which may impede or even make impossible the use of certain machines.

Willow may be cultivated on non–wetland, moist Grades IVa and IVb soils of the weak cereal–fodder Complex. It may be cultivated on Grade IVb or V soils made up of sands and included in the good Secale Complex, bearing in mind the fact that groundwater in such soils should occur no deeper than 250 cm. In the case of energy crops, there is the possibility of using weaker soils of lower quality grades, but only in the case of intensive fertilization and irrigation during dry periods. Willow plantations may be established on soils excluded from agricultural production for food purposes due to their salt content. In the case of dry soils, during seasons with low precipitation, the harvest are up to 30% lower than on moist soils This makes the cultivation of willow uneconomical.

Many factors have an impact on willow harvest. They include soil and hydrological conditions, the selected and used variety, and fertilization

(Kalembasa et al. 2006a; Rockwood et al. 2004; Stolarski et al. 2007; Kalembasa et al. 2009; Labrecque et al. 1993, 1994, 1997). Willow shrubs cultivated in Poland are estimated at approximately 15 t d.m. ha^{-1} $annum^{-1}$ (Stolarski 2003; Szczukowski and Stolarski 2005; Szczukowski et al. 2005a, b). At a planting density of 40,000 per hectare and fertilization at a rate of 75 kg ha^{-1} N, 50 kg ha^{-1} P_2O_5, and 75 kg ha^{-1} K_2O on Complex 8 soils (heavy black soil) with annual harvest cycles, the yield in the first year of cultivation amounts to 10.8 tons d.m. ha^{-1} (maple 1054), 17.2 tons d.m. ha^{-1} (maple 1052), 14.1 tons d.m. ha^{-1} (maple 1047), and 16.6 tons d.m. ha^{-1} (maple 1023). In the second and third years the harvest amounted to 12.4 and 11.5 tons d.m. ha^{-1} (maple 1054), 13.7 and 10.1 ton d.m. ha^{-1} (maple 1052), 12.7 and 12.8 ton d.m. ha^{-1} (maple 1047), and 12.6 and 10.0 ton d.m. ha^{-1} (maple 1023). At the same planting density and fertilization on medium soil of Complex 4, three successive years of cultivation yielded harvests amounting to 14.0, 12.1, and 12.7 tons d.m. ha^{-1} (maple 1054), 13.1, 10.8, and 10.8 tons d.m. ha^{-1} (maple 1052), 12.7, 9.4, and 11.2 tons d.m. ha^{-1} (maple 1047), and 13.4, 11.0, and 11.2 tons d.m. ha^{-1} (maple 1023) (Faber et al., 2007). In the case of harvests every three years on Complex 8 soils (heavy black soil), harvests amounted to 11.7 tons d.m. ha^{-1} $annum^{-1}$ (maple 1054), 16.0 tons d.m. ha^{-1} $annum^{-1}$ (maple 1052), 15.8 tons d.m. ha^{-1} $annum^{-1}$ (maple 1047), and 18.3 tons d.m. ha^{-1} $annum^{-1}$ (maple 1023), while on medium Complex 4 soils the yield was 15.2 tons d.m. ha^{-1} $annum^{-1}$ (maple 1054), 13.4 tons d.m. ha^{-1} $annum^{-1}$ (maple 1052), 15.2 tons d.m. ha^{-1} $annum^{-1}$ (maple 1047), and 13.6 tons d.m. ha^{-1} $annum^{-1}$ (maple 1023) (Faber et al. 2007). In the case of all other examined maples cultivated, harvest every three years gave larger yields than in the case of annual harvests.

Mineral, organic, and inexpensive sewage sludge, filtered effluent from waste dumps, and water from secondary treatment of sewage may be used in the fertilization of willow shrub plantations as the plant uses contained nutrients efficiently (Romanowska–Duda 2009; Kuś and Matyka 2010). The recommended quantities of fertilizer may be decreased by 10%–20% in the third and further years of cultivation because the plants reuse a part of the nutrient components found in falling leaves (Szczukowski et al. 2004). An absence of mineral fertilization results in a drastic 42% to 60% fall in harvests. The willow is significantly more sensitive to an absence of mineral fertilization than the miscanthus. Lack of potassium fertilization lowers willow yields by an average of 7%. This indicates a lower sensitivity to shortages of this element than in the case of the Virginia mallow. However, an absence of phosphorus fertilization lowered harvests by 22%. The role of phosphorus fertilization in the cultivation of the miscanthus and Virginia mallow is significantly lower. The willow also indicates a relatively small sensitivity to soil acidity. Cultivation on pH=4.2 soil lowered yields by just over 7% with respect to pH=6 soils (Łabętowicz and Stępień 2010).

Both diseases and pests are a threat to willow plantations. Diseases caused by fungus include rust (*Melampsora* sp.), leaf and shoot spotting (*Trichometasphaeria* sp.), blight (*Venturia* sp.), and anthracnose (*Aureobasidium* sp.). Also threatening are *Venturia chlorospora*, *Physalospora miyabeana*, and *Rhytisma salicinum* (Błażej 2007). The presence of phytophages during the first year of growth or on one–year basal shoots may cause a significant fall in the quantity and quality of the willow harvest. It is for this reason that it is particularly important to apply costly protection for young plantations (Czerniakowski 2005).

2.3. Miscanthus giganteus

The *Miscanthus* x *giganteus* is a perennial grass of southeast Asian origin. It is one of twenty species of miscanthus developed as a result of the cross breeding of Chinese silver grass (*Miscanthus siniensis*) and Amur silver grass (*Miscanthus sacchariflorus*). It has a strongly developed system of rhizomes and the expansive root system reaching over 2.5 m into the earth. Such an underground structure may be used to prevent erosion (Wersocki 2008). This plant uses C_4 carbon fixation (photosynthesis). This is in contrast to C_3 carbon fixation that is used by most plants in the Polish climate. In it there is no respiration during CO_2 assimilation in which 1/5 to 1/3 of the gas is released into the atmosphere (Osińsko 1996). The lack of CO_2 losses results in more rapid biomass increase and a higher carbon content in the plant tissue (Wersocki 2008). This grass forms large clumps made up of thick blades filled with a spongy core, where over 200 may make up a single plant. Miscanthus achieves a height of 200–450 cm. It has been cultivated in Europe for over eighty years. Initially it was an ornamental plant, but for over eighteen years it has been grown on energy plantations. Various studies have been conducted in Great Britain since 1990 on miscanthus biomass production subject to various conditions of temperature, solar insolation, water availability, and various soil conditions (Bullard et al. 1995; Nixon 2001; Ozimek 2009; Kuś and Matyka 2010). The plant is characterized by quick growth, high harvest yields per unit area, and resistance to low temperatures (Bullard et al. 1995; Nixon et al. 2001b).

In the first year of cultivation the harvest amounts to approximately 8 t d.m. ha^{-1}, while in the second it reaches 25–45 t d.m. ha^{-1} (Scurlock 1999; Danalatos 2007). This is at least ten times more than can be achieved by cultivating one hectare of forest (Oniśko 1996; Wersocki 2008). Annual harvests subject to the climatic conditions of Great Britain amount to 12–16 t d.m. ha^{-1}, Denmark 15–25 t d.m. ha^{-1}, and Austria 22 t d.m. ha^{-1} (Nixon and Bullard 1997; Scurlock 1999). In Poland the output of a several year old plantation reaches 20 t d.m. ha^{-1}. The service life of a miscanthus plantation is from ten to twenty–five years (Bullard and Metcalfe 2001; Wersocki 2008).

It has been confirmed that the *Miscanthus giganteus* has a broad scope of tolerance with respect to soils and pH (Nixon 2001). Subject to Polish climatic conditions, the cultivation of this plant should be concentrated on Grade IVb soils of a good Secale Complex. The structure of the root system makes possible the cultivation of the miscanthus on moderately cohesive Grade IVa and IVb soils with a low level of ground water (Kolowca et al. 2009). According to simulations conducted for Eastern Europe, in the case of very good soils subject to such conditions it is possible to achieve 17.7–21.8 t d.m. ha^{-1}, and 12.9–17.1 t d.m. ha^{-1} on good soils (Fischer et al. 2005). However, German experience demonstrates that on good soils it is possible to achieve up to 24 t d.m. ha^{-1}, but only 2–10 t d.m. ha^{-1} on poor soils (Surlock 1999). Applying a planting density of 15,000 (*Miscanthus* x *giganteus*) per hectare and fertilization amounting to 75 kg ha^{-1} N, 50 kg ha^{-1} P_2O_5, and 75 kg ha^{-1} K_2O on Complex 8 soil (heavy black soil), the yield achieved over three successive years was 9.0, 21.7, and 18.0 t d.m. ha^{-1}. With the same planting density and fertilization on Complex 4 medium soil, three successive annual harvests gave 10.4, 19.2, and 14.9 t d.m. ha^{-1} (Faber et al. 2007; Kuś et al. 2008). Harvests of miscanthus and willow dry matter on heavy black soil were similar in a three–year cycle. However, on medium soil the miscanthus gave a yield significantly better than that of the willow. During a very dry third year of cultivation, the harvest for miscanthus was approximately 50% greater than that of the one year basal shoots of the willow shrub (Faber et al. 2007).

Miscanthus plantings using seedlings produced in laboratories *in vitro* should amount to 10,000 to 12,000 plants per hectare with rows every 75–100 cm and distances between plants in the rows of 60–100 cm. Fifty to 100 cuttings may be received from one well–developed rootstock after three to four years of cultivation. Plants developing from such cuttings are already more deeply rooted in their first year. Because of this they are more resistant to damage caused by low temperatures than seedling produced using the *in vitro* method. Miscanthus biomass may be harvested during the period from November to December when its moisture content amounts to 35%–45%, or from March to April when water content falls to 25%–30% and elements unfavorable from the point of view of energy—chlorine, potassium, and sodium—are also lower. The negative aspect of the later date is lower yields due to the falling of leaves. Losses reach 15%–20% with respect to the late–autumn harvest.

The miscanthus' fertilization needs in the year of the establishing of the plantation are small. A total of 30 kg ha^{-1} N, 20 kg ha^{-1} P_2O_5, and 40 kg ha^{-1} K_2O are sufficient. A larger dosage of N–P–K is recommended starting with the second year—90 kg ha^{-1} N, 30 kg ha^{-1} P_2O_5, and 80 kg ha^{-1} K_2O. During the drying of plant shoots, large quantities of nutritional ingredients move to the rootstock, while through falling leaves, a part of them return to the soil. Thanks to this only small quantities of fertilizer components are removed from the field with the biomass harvest. Studies have demonstrated that applying N–P–K fertilizer at the recommended ratio of 2:1:1 did not significantly change the ash content (~3%). However, application of sewage sludge at a rate of 20 t ha^{-1}, which has a favorable impact on yield, decreased the quantity of ash after burning to approximately 2.5% with respect to the unfertilized control sample (3%). Sewage sludge applied at a rate of 10 and 40 t ha^{-1} increased ash quantities to 4% and 5%, respectively (Kacprzak et al. 2010).

Lack of mineral fertilization in the first year of cultivation resulted in a lowering of the harvest by approximately 25%. The role of mineral fertilization over successive years of cultivation is significantly smaller. It resulted in a fall in harvest yields by 10%–13% as compared with a full dosage of Ca–N–P–K. Miscanthus is significantly less sensitive to a lack of mineral fertilization than the willow. Study results show that the miscanthus is best adapted to utilize natural soil nutrient component resources subject to conditions of sandy soils (soils with a clay–sand granulometric make up). Absence of nitrogen while maintaining dosages of the remaining component lowered the harvest by a total of 43.5%, while an absence of N–P–K fertilization resulted in a fall of only 15.8%. Cultivation of soils with pH=4.2 lowered harvest yields by just over 7% as compared with soils of pH=6 (Łabętowicz and Stępień 2010).

Up to now, disease and pests were not a significant threat to miscanthus cultivation. Only a single viral disease is known that results in inhibited growth and chlorosis. However, it does not spread from plant to plant. Its source is infected seedlings (Wersocki 2008). Plantations existing in Poland have noted damage to miscanthus stems caused by the feeding of fly larvae as well as leaf damage characteristic of the feeding of the corn ground beetle (*Zabrus tenebroides* Goeze). In a longer timeframe, with an increase in the area of cultivations, this beetle from the ground beetle family may prove a major pest because miscanthus plantations provide it with potential for development. This will force the application of costly plant protection efforts (Mrówczyński et al. 2007).

In the case of the cultivation of miscanthus on good Secale Complex soils of Grade Iva quality that are acidic (pH=4.1), both the application of inexpensive sewage sludge (63 t ha^{-1}) and N–P–K fertilization at a dosage of 90:70:90 kg ha^{-1} as well as half that dosage had an impact on improving plant growth. N–P–K mineral fertilization using a full dosage resulted in an increase in plant height as well as mass by 44.4% and 96.1%, respectively, sewage sludge by 24.7% and 81.3%, respectively, and a half N–P–K dosage by 27.1% and 60.4%, respectively (Lisowski and Porwisiak 2010).

2.4. Switchgrass

Panicum virgatum has been grown in the United States as protection of the soil against erosion as well as animal fodder for the past fifty years. Studies conducted as of the nineteen–thirties have provided valuable data and led to the creation of many varieties designated for soil protection and as animal feed (Vogel 2000; Vogel and Jung 2001). As of the nineteen–nineties, the plant has been used by the United States Department of Energy as a model herbaceous energy plant for the production of bioethanol and electricity (Lemus et al. 2002; Schmer et al. 2006; Mulkey et al. 2006; 2008; Tober et al. 2007).

In Canada, the Resource Efficient Agricultural Production (REAP) organization has been working on the use of the *Panicum virgatum* for the production of biomass for energy purposes, bioethanol, and pulp for the production of paper since 1991. Intense research into the *Panicum* has resulted in an increase in the harvest yields of this pant, while most recent filed tests have shown that the cost of cultivation in the United States is a mere USD 46.00 per ton (Bals et al. 2010). A recent economic study in Nebraska, South Dakota, and North Dakota indicated that producers can grow switchgrass at a farm gate cost of USD 60/ton (Perrin et al. 2008). Producers with experience in growing switchgrass had five–year average costs of USD 43/ton, and one producer grew switchgrass for USD 38/ton. These costs include all expenses plus land costs and labor at USD 10/hour. Each ton of switchgrass represents 80 gallons (302.8 l), with a farm gate cost of USD 0.75/gallon at USD 60/ton. This research indicates that growing switchgrass for cellulosic ethanol is economically feasible in the central and northern Great Plains. It should be noted that fuel and land prices have increased since this study, so the cost increases for those inputs need to be considered when determining switchgrass production costs. (Perrin et al. 2008; Mitchel et al. 2012). Until recently, the *Panicum virgatum* was only known as an ornamental grass in Europe (Elbersen et al. 2000).

According to studies and simulations conducted in central Canada, switchgrass is a more promising energy plant than willow for those climatic and soil conditions. This is mainly due to the significantly lower overall costs of production of one ton of dry matter and better adaptation to hydrological and soil conditions (Girouard et al. 1995).

Studies conducted on a large scale (cultivation on fields with an area of three to nine hectares) have demonstrated that the cultivation of *Panicum virgatum* as an energy plant designated for biomass produces over 500% more renewable energy than it uses. Moreover, total greenhouse gas emissions resulting from the production of bioethanol using *Panicum virgatum* is 94% lower than in the case of gasoline (Schmer et al. 2008).

Among the benefits of cultivating switchgrass are:

- Large net energy production per hectare,
- Low costs of cultivation,
- Small nutrient requirements,
- Low ash content,
- Efficient water use,
- Adaptation to various geographical latitudes,
- Cultivation easy to start from seeds,
- Potential for adapting the plant to grow on non–agricultural soils that are too weak and degraded, and
- Capability of biological capture and storage of carbon dioxide.

Studies have demonstrated that the cultivation of switchgrass in Europe may be conducted on land significantly more to the north than is the case in North America. This is a result of climatic conditions, which are more moderate due to the presence of oceans.

Switchgrass is a C_4 type plant that has additional mechanisms for tying CO_2 through anatomical and physiological mechanisms, which makes possible an increased concentration of CO_2 in the cells (Gołaszewski 2011). The effect is that such plants have a quicker photosynthesis and greater biomass efficiency with a relatively small demand for water. They account for less than 5% of the world's flora. From an energy point of view, they are the most sought after plants. Apart from switchgrass (*Panicum virgatum* L.) they include common corn (*Zea mays* L.), miscanthus (Amur silver grass, Chinese silver grass, *Miscanthus giganteus—Miscanthus* sp.), sorghum (*Sorghum* sp.), and sugar cane (*Saccharum officinarum* L.) (Gołaszewski 2011).

Switchgrass is more resistant to drought than miscanthus and has achieved better harvests per hectare subject to unfavorable hydrological conditions.

Switchgrass may grow on many types of soil. It has a deep and very developed root system. Thanks to the phenomenon of mycorrhiza it can efficiently take up phosphorus. It can be cultivated on shallow and rocky soils, subject to erosion and with little water capacity as well as occasional flooding. *Panicum* cultivated on soils with a low pH give significantly higher harvests than other grasses in a moderate climate or than energy plants such as the common osier (*Salix viminalis*) (Elbersen et al. 2004).

The primary difficulty in cultivating this plant is fighting weeds, which are particularly threatening to energy plants that are slow growers in their first year (Elbersen et al. 2004; Bendfeldt et al. 2001; Shrestha and Lal 2006).

Panicum virgatum harvests are dependent on the soil and climate conditions of the site of cultivation and may range from 6 t d.m. ha^{-1} in the case of poorly fertile soils in northern Europe to over 25 t d.m. ha^{-1} in fertile soils found in the southern zone (Elbersen et al. 2004). Harvests achieved on Upper Great Plans United States farms range from 5.2 to 11.1 tons ha^{-1} and deliver 60 GJ of energy per annum (Schmer et al. 2008). In the case of proper cultivation it is possible to achieve long–term production stability lasting over fifteen years.

Subject to long–term drought and during pre–winter drying, perennial high prairie grasses such as switchgrass and cordgrass are capable of the translocation of 30% of the nitrogen found in their above–grade parts into their roots and rhizomes (Chołuj et al. 2008; Elbersen et al. 2004).

It has been demonstrated that switchgrass cultivated subject to northeastern European conditions has sufficient nitrogen resources from the soil, remobilized from the roots, and deposited from the atmosphere. In the case of very infertile soils and irrigation, nitrogen fertilizer may be unnecessary. Up till now diseases have not been a problem in the cultivation of *Panicum* in Europe, which does not require plant protection operations.

Depending on the type of soil, optimum production is achieved in the 2–3 year for light soils and the 4–5 year for heavy soils. The first–year harvest is small and may be uneconomical in northern areas. The second–year harvest amounts to 8–10 tons of dry matter per hectare and increases further in the third year. Early frosts and drought may delay the full harvest potential (Elbersen et al. 2004; Fike et al. 2006; Monti et al. 2001; Parrish and Fike 2005).

Switchgrass has a total lignin content of approximately 17.6%, cellulose 31.0%, and hemicellulose 24.4% (USDE). Cellulose and lignin content in biomass is important in biochemical processing by way of methane or alcohol fermentation. The conversion of lignocellulosic biomass into ethanol is an environmentally–friendly alternative to petroleum (Bals et al. 2010). The biodegradability of cellulose is higher than that of lignin, which means that biomass with low lignin content is more useful for fermentation processes.

Moreover, the spatially mutual placement of lignin and cellulose in biomass has an enormous impact on possibilities of utilizing cellulose as raw material for fermentation (Pulaski et al. 2010). *Panicum* biomass is receptive to preliminary processing and hydrolysis. According to research by Balsa et al. (2010), there is an over 90% conversion of the hydrocarbon cell walls into simple sugars. The energy value for cellulose may change slightly depending on the quality of the raw material, where the average heat of combustion amounts to 17.4 MJ kg^{-1} while that for lignin is 21.2 MJ kg^{-1}. The lower heat of combustion for cellulose is caused by its higher level of oxidation (Podlaski et al. 2010).

3. Economic analysis of the production of selected energy plants

Growth in interest in perennial energy plants on the part of potential planters, including increase in increasing cultivated area, is dependent on the profitability of production. It should be assumed that such profitability must be higher than the profitability of cereal or rape production for consumption. It is only then will farmers be interested in such cultivation. In the event of just slightly higher or lower production profitability, compared with growing annual farming plants, there will be no increase in area for energy cultivation on agricultural land. This stems from the fact that multiyear energy crop plantations are established once every ten to twenty–five years, where initial costs are high and there is no return until after several years—longer than in the case of annual crops. Moreover, the cultivation of such plants is, from the point of view of the farmer, encumbered by significantly higher risk than one–year cultivations (Stuczyński et al. 2008; Kwaśniewski 2011).

Discussions underway in the scientific community as well as public opinion see the risk of an increase in the prices of plant products resulting from the appearance of new sources of demand from the energy sector that will compete for space with demand for plant products as generated by the food sector. These concerns are also justified by reports by international organizations such as those of the FAO and OECD. They point to forced demand for biofuels, which may lead to growth in competition for agricultural space and an increase in food process (OECD–FAO, 2007). Newer studies project a fall in the prices of cereals by 2020, which will make investments in energy crop plantations more profitable (OECD–FAO, 2011). The development of second–generation biofuels will work to decrease the use of raw materials derived from annual plants serving the production of first–generation biofuels in the energy industry. Second–generation plants may be cultivated with relatively large efficiency on soils that are not suitable for food–oriented cultivation. In their turn, the development of third–generation biofuels may lead to a complete independence of production from soil quality and hydrological conditions, where only solar insolation and temperature will be determinants. Bearing in mind these factors and applying an appropriate policy of agricultural spatial management, the risk of increased price for food due to energy biomass production will fall.

Estimating plantation costs is rather difficult due to the very large number of variables with an effect on it, the continuous development of agricultural technology, the specifics of individual countries or even regions, and the incomplete data available in literature. This may result in both over– and under–estimation. Growth in the number of commercial plantations will lead to the optimizing of planting and harvesting processes as well as improved management. In its turn, this will play a role in continued falling prices. On the other hand, increases in energy costs will result in higher fertilizer and transportation costs (Faasch and Patenaude 2012).

The three most frequently cultivated energy plants in Poland are the common osier, the Virginia mallow, and the *Miscanthus giganteus*. Production profitability, understood as the relation of the value of achieved production to costs incurred to produce it, is different for each of those species. In light of the specifics of cultivating perennial energy plants, significant costs must be borne when establishing the plantation. It is necessary to take into account the readying of the fields (soil analysis, machine and tool use, materials such as fertilizer, herbicides, etc., and labor costs), the procurement or production of seedlings, inclusive of transportation, planting (use of machines and tools, labor costs), and tending throughout the growing season (use of machines and tools, materials such as fertilizers, pesticides, etc., labor costs). The costs incurred will vary significantly depending on plant species and the scale of the venture (manual or machine effort). From among the most frequently cultivated species in Poland, the decidedly highest costs of establishing a plantation are incurred in the case of the miscanthus. This is due to the high costs of procuring cuttings (this plant does not produce seeds). Depending on their quality (number of basal shoots and possible damage), type (root cuttings received from an existing plantation or reproduced using the *in vitro* method), and the volume of the order, prices may range from PLN 0.35 all the way up to approximately PLN 1.50. The planting density ranges from 10,000 to 18,000 plants ha^{-1}. This gives an average of PLN 15,250 (PLN 3,500 to PLN 27,000) for planting material necessary to establish one hectare of plantation. What is most often done in practice is a planting density of 12,000 plants ha^{-1}, where cuttings of good quality may be purchased at PLN 0.70. Such a price is offered in the case of the purchase of quantities as needed to plant up to 50 ha, which gives PLN 8,400/ha. In the case of large areas of approximately 100 ha, the price may fall to PLN 0.50, which generates a cost of PLN 6,000/ha. The costs of establishing one hectare of miscanthus plantation in 2008 (Matyka 2008) were calculated at PLN 21,871, while a 2009 analysis assuming complete mechanization as conducted on Vattenfall (by Bio Energia) stated a price of PLN 20,640 (Vattenfall 2009). The cost of establishing one hectare of willow plantation in 2008, depending on planting method, amounted to PLN 8,732–9,231 in 2008 (40%–43% of the costs of establishing a miscanthus plantation) and PLN 6,575 in 2009 (31.8% of the costs of a miscanthus plantation). However, in the case of the Virginia mallow, the costs amounted to PLN 9,721–11,349 (44%–53% of the costs of establishing a miscanthus plantation) and PLN 7,775 (36.7% of the costs of establishing a miscanthus plantation).

Analysis of the costs of existing plantations performed in 2011 (Kwaśniewski 2011) defines the average cost of establishing a plantation at PLN 5,328.7 ha^{-1}. Smaller plantations (up to 5 ha) had decidedly higher costs (PLN 6,481.4 ha^{-1}), while for larger plantations (over 5 ha) they amounted to PLN 4,176.1 ha^{-1}. The highest share in tangible costs was for seedlings. On average, they amounted to PLN 2,688 ha^{-1} (92.7% of tangible costs) for the group of plantations up to 5 ha, while for the group of plantations over 5 ha these costs amounted to PLN 1,152 ha^{-1} (75.5% of tangible costs). For all examined plantations the assessed costs are PLN 1,920 ha^{-1} and their share in the cost structure is 84%. In the case of larger plantations of the second group, in three out of five cases, owners used seedlings from what are known as mother plantations, which had a significant impact on the lowering of the costs of planting material. It is also for this reason that the costs were significantly lower in the second group. Harvesting and harvested matter transportation costs were decidedly dominant in production costs. They amounted to from PLN 3,110.1 ha^{-1} on plantations where harvesting was conducted using combustion engine brushcutters to PLN 7,833.6 ha^{-1} for plantations where Mengele self–propelled forage harvesters (this was the only plantation where biomass was harvested in the form of chips). The annual depreciation costs related to the establishing of a plantation were in the PLN 327/7 to PLN 1,048.9 ha^{-1} range. Total biomass production costs amounted to from PLN 3,942 ha^{-1} for plantations using disc mowers to PLN 8,435 ha^{-1} for plantations with self–propelled harvesters.

Differentiation in the costs of establishing a plantation is linked with the method of planting and is highest in the case of mallow. The most expensive method of establishing a plantation is using hand–planted rooted cuttings, while the least expensive is direct sowing of seeds into the soil (Matyka 2008). In each case a significant share in the cost structure is made up of plant material that, in the case of the miscanthus planted using a transplanter, amounts to 71% of the costs of establishing a plantation and 24% of overall costs. In the biomass production process using energy willow, in addition to the costs of establishing and operating the plantation, it is necessary to take into account the costs of its liquidation. Stolarski et al. (2008) put them at PLN 2,075 ha^{-1}, while in other studies they were calculated at PLN 1,129 ha^{-1} (Matyka 2008) and PLN 1,078 ha^{-1} (Vattenfall 2009).

Calculations performed in 2008 (Matyka, 2008) point to a very interesting phenomenon. A comparison of the cost and revenue parts in calculations demonstrated that in the case of all energy plants encompassed by analysis, revenues from such production did not cover costs. Analysis indicated that the main source of revenues for farmers managing energy–oriented plantations is the value of production (82%) and direct subsidies (13%). The calculations conducted by the authors took into account subsidies then in effect on the cultivation of energy plants (5% of revenues). Presently, such subsidies are no longer available. However, subsidies have been introduced for short–rotation forest tree groves, which include the willow.

According to calculations conducted in Germany, the preparing of the field (mechanical and chemical operations) for willow and poplar cultivation amount to EUR 281.8 ha^{-1} on average. On average, the cost of machine planting of plants is EUR 0.04 per plant. The costs of seedlings (cuttings) of the poplar and willow amount to EUR 0.20 and EUR 0.08, respectively, when the reproductive material is bought on the open market, and EUR 0.15 and EUR 0.04 for reproductive material produced in–house. In the case of willow plantations the planting density amounts to from 18,000 to 32,000 plants ha^{-1}, while in the case of the poplar it is approximately 12,000 plants ha^{-1}. The costs of fertilization amount to EUR 155.5 ha^{-1} $annum^{-1}$. Harvesting, drying, and transporting biomass was estimated at EUR 40.8 t^{-1} d.m. Assuming an average yield at a level of 11.6 t d.m. ha^{-1} $annum^{-1}$ (Germany), this works out to be EUR 473.28 ha^{-1} $annum^{-1}$. Liquidation of the plantation costs EUR 1,023 ha^{-1}, which in the case of a twenty–year cultivation gives EUR 51.15 ha^{-1} $annum^{-1}$. An interesting conclusion stemming from the analysis is that SRC production is more profitable in Germany than in Poland or Northern Ireland, which is the result of the significantly lower costs of chips in those countries (Faasch and Patenaude 2012).

Of the ten plantations encompassed by analysis in 2011 (Kwaśniewski 2011), only in the case of two can biomass production be profitable at an assumed price of PLN 120 t^{-1}. In the case of a successive two, such production will generate profits at a price greater than PLN 150 t^{-1}, with four assuming a price of PLN 170 t^{-1}. Achieving such a high price for the sale of fresh, unprocessed biomass in the nearest future is highly improbable. The extremely diverse profitability indicators for biomass production (at assumed prices) confirm the suggestions of many authors that the production of biomass using energy willow in the current macro–economic conditions in southern Poland is not profitable.

4. Logistic strategies for biomass deliveries

Criteria for sustainable development with respect to biofuels and bioliquids have been defined in order to implement the requirements of Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources. These criteria detail the restriction of greenhouse gas emissions by at least 35%, where it is assumed that there will be an increased reduction in the emission of these gasses by 50% up to the year 2017 and by 60% as of January 2018. Calculations of gas emissions should be provide in **life cycle assessments** (**LCA**), which is intended to assess potential threats to the environment. The essence of this method is estimating and assessing the consequences of the entire technological process as well as management strategies for it with respect to the natural environment. The analysis should encompass the entire system, from raw material production to the final product, including the impact of biomass transportation on energy, economic, and environmental efficiency.

As to national energy policy, the basic document that is in effect is “Energy Policy Up to the Year 2030” (in Polish) as approved by the Council of Ministers on January 4, 2010, which includes energy safety and respect for environmental protection (Ministry of the Economy 2010). Developed logistic operations should provide for interdisciplinary engineering of the systems and encompass services for the entity (the plant biomass producer), demand projections, information flow, stock monitoring, the rational storage of plant biomass, contracting and the supply of production plants in agrobiomass, and the organization and management of delivery transportation. Logistic systems should take into account planned optimum costs during performance of operations. In order to increase energy production using renewable sources, it is vital to optimize the logistics of deliveries of raw material and the development of public awareness relating to aspects of business management. To date, many works have appeared on the design of biomass supply strategies and management systems aimed at generating energy from second–generation biomass (Brougliéri and Liberti 2008; Dunnett et al. 2008). Sokhansanj et al. (2006) described the dynamic model of consolidated logistics with the biomass load. This model facilitates the simulation of the entire process from raw material sourcing, storage and warehousing all the way to biomass transportation. Bearing in mind the low level of biomass production in certain regions of Poland, individual system modeling is necessary. Also worthwhile is continued interdisciplinary development that will take into account the individual needs of the country's regions for efficient and stable biomass supply.

5. Conclusions

Appropriate policy of agricultural spatial management, will decrease the risk of increased price for food due to energy biomass production. Profitability of energetic plants cultivation must be higher than the profitability of cereal or rape production for consumption. In the event of just slightly higher or lower production profitability, compared with growing annual farming plants, there will be no increase in area for energy cultivation on agricultural land. The development of second–generation biofuels will work to decrease the use of raw materials derived from annual plants serving the production of first–generation biofuels in the energy industry. Choosing the right energy plant species adapted to the habitat, and to create a local market of biomass are the two most important determinants of profitability of the investment.

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Streszczenie

ANALIZA EKONOMICZNA I STRATEGIE LOGISTYCZNE PRODUKCJI BIOMASY WYBRANYCH ROŚLIN ENERGETYCZNYCH

Celem nieniejszego artykułu było przeprowadzenie analizy produkcji wybranych roślin energetycznych, które w Polsce są już podstawowym źródłem agrobiomasy. W treści analiza zawierała aspekty środowiskowe i uwarunkowania produkcji biomasy na cele energetyczne dla ślazowca pensylwańskiego (Sida hermaphrodita), wierzby wiciowej z rodzaju Salix,i miskanta olbrzymiego (Miscanthus x giganteus) i prosa rózgowatego (Panicum virgatum). Przedstawiono analizę ekonomiczną produkcji wybranych roślin energetycznych z uwzględnieniem kosztów plantacji i ich opłacalności oraz zasygnalizowano strategie logistyczne dla dostaw biomasy w celu zabezpieczenia stałej produkcji energii odnawialnej w zrównoważonym rozwoju.

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Use of Sewage Sludge in the Production of Plant Biomass for Energy: Biological and Economic Conditions

Abstract

The goal of this article is a presentation of the legal, biological, and economic conditions of energy production using biomass, especially taking into account the application of sewage sludge certified for natural use in agriculture. Any increase in the production of biomass necessitates the introduction of cheap and highly–efficient plant production technologies that are environmentally–friendly. Use of certified sewage sludge can increase the economic efficiency of energy crops and have a beneficial impact on the environment.

1. Introduction

Care for the natural environment in combination with concurrent climate change and a diversification of the power engineering mix are directing the attention of experts at the need to produce energy from renewable sources in order to satisfy the energy needs of Poland (Grzesik and Romanowska-Duda 2009, Romanowska et al. 2011). This direction is in line with European Union

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policy. The assumed "3x20" targets, including the achievement of a 20% share in renewable energy by the year 2020, obligates all European Union member states to achieve this goal. Such action is aimed at making Europe independent of imported fuel and price fluctuations on world market.

The planned 20% share of energy from renewable energy sources is an average value for the countries of Europe. Poland has obligated itself to achieve a 15% value in renewable energy sources for the whole of energy used in the country by the year 2020. The national action plan assumes a 19% share for electricity, 17% for thermal energy, and 10% for transportation biofuels. The share of electrical energy derived from renewable energy sources amounted to 7.86% at the end of 2011. Initial assumptions had put the value at 8.85%. This energy shortage in Poland indicates a need to create stable, long–term principles for supporting domestic producers.

2. Conditions for acquiring energy from renewable sources

Among the most rapidly developing areas of the green economy in Poland is renewable energy, especially as based on biomass. Another growth area is biofuels that are attracting the attention of farmers, as is the construction of modern sewage treatment plants (Romanowska-Duda et al. 2011, Kacprzak et al. 2012). Apart from direct subsidies and a credit system, companies planning the development products supporting the green economy can count on the support of the Ministry of Environment in the form of the GreenEvo – Green Technology Accelerator. Alternative energy sources are achieving unheralded public acceptance. Governments around the world are setting concrete targets for the renewable energy sector that are favorable for companies producing energy, including from plant biomass.

Biomass delivers 3% of total primary energy in the industrialized nations. It is mainly used in heating applications and in combined electricity and heat generating plants. Currently, the market encompasses home heating, major industrial and municipal combined electricity and heat generating plants, and co–combustion in major coal–based power plants (Grzesik et al. 2011).

According to projections up to the year 2050, global use of biomass for heating and industrial power engineering will double. In line with scenarios assuming a normal course of events, the share of energy received from biomass will increase from the present 1.3% of all energy produced to 2.4%–3.3% by the year 2030. This means an average annual growth rate of 5%–6%.

Increasing efficiency and developing new technologies is an exceptionally important component factor of the green economy. In many fields there exists the possibility of optimizing products, including energy crop biomass and energy extracted from it. In implementing optimum technologies for acquiring plant biomass, it is possible to decrease the negative environmental impact of municipal waste and increase the area of such crops by using bio–stimulators on marginal soils that are not used in food production (Grzesik and Romanowska-Duda 2009a, Romanowska-Duda et al. 2009, Grzesik et al. 2011a).

The surface area of devastated and degraded soils that require recultivation and management at the end of 2011 amounted to 64,000 ha (0.2% of the total surface area of the country). The degree of these degradation and devastation processes does not show any major differentiation by voivideship (province)—from 0.1% of the total surface area of the Podkarpackie Voivodeship to 0.4% of the Dolnośląskie and Śląskie voivodeships. However, it is a significant problem in highly industrialized areas. Only 1,770 ha were recultivated in 2011, and a total of 629 ha were developed, mainly for forestry and agricultural objectives (Concise statistical yearbook of Poland 2012).

The least expensive technologies, those whose implementation costs are the lowest, have the greatest chances for large–scale implementation. It is for this reason that the production of energy crops for biomass and its co–combustion in existing power–generating boilers has the greatest chances of development (Grzesik et al. 2011b). Adapting electricity and combined electricity and heat generating plants to use this technology requires only moderate investment outlay. Depending on technical solutions, the share of biomass for co–combustion amounts to 8%–12%, where in more advanced technologies it achieves a level of 40%–60%. High hopes for the intensification of biomass production for energy needs are tied with the application of processed sludge from municipal sewage treatment plants, which fosters the rapid growth of plants while the problem of storing sludge is simultaneously solved through its use in agriculture (Grzesik and Romanowska-Duda 2009c, Romanowska-Duda et al. 2009).

3. Using sewage sludge in agricultural production: EU legislative basis

Council Directive 86/278/EEC of June 12, 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (Official Journal of the European Union L 181 of July 4, 1986, p. 6 and L 377 of December 31, 1991, p. 48. Article 3) is a basic legal act on the use of sewage sludge. The purpose of this directive on the use of sewage sludge in agriculture is the defining of principles governing its use so it do not bring about a worsening of the quality of the soil and agricultural products. The directive assumes that the sludge from sewage treatment plants from domestic and municipal sewage effluent as well as effluent from other sewage treatment plants cleaning sewage of a composition similar to that of the effluent from domestic and municipal sources may be used in agriculture pursuant to the provisions of the directive, bearing in mind the provisions of directives 75/442/EEC and 78/319/EEC. This reservation indicates that sludge from cesspools and similar systems designated for sewage treatment may be used in agriculture, depending on conditions considered necessary by the given member state in order to protect human health and the environment and only if its application is regulated by regulations established by the given member state.

In its turn, Polish law has created the Act on Waste of April 27, 2001 (Journal of Laws 2001, No. 62, item 628, with subsequent amendments and Journal of Laws 2010, No. 185, item 1243, uniform wording) as well as the Directive of the Minister of Environment of July 13, 2010 on Municipal Sewage Sludge (Journal of Laws 2010, No. 137, item 924). Pursuant to these legal acts, municipal sewage sludge is defined as originating from sewage treatment plants from digestion chambers or other systems for the treatment of municipal sewage effluent as well as other effluent of a composition similar to that of municipal sewage. It may find application in agriculture after prior processing.

Municipal sewage sludge may be used in:

1. Agriculture, for the growing of all agricultural produce allowed for trading, including crops designated as fodder,
2. The recultivation of land, including land designated for agricultural use,
3. The growing of plants designated for composting, and
4. The growing of plants not designated for food or fodder.

Such sludge may be provided to the owners, tenants, or other persons managing the property on which it is to be used only by the producer of the sludge. The producer bears responsibility for the proper application of municipal sewage sludge as specified in items 1–4 (Bień et al. 1998, Jarosz – Rojczyk 2004).

Municipal sewage sludge may be used if conditions relating to the following are met:

- The use of the sludge causes no worsening of soil quality,
- Sanitary standards for the applied sludge,
- Heavy metal content in the sludge,

- Heavy metal content in the topsoil (0–25 cm), and
- Soil pH (5.6).

The preparing of sewage sludge for use in agriculture involves (Miksch and Sikora 2010):

- Biological, chemical, thermal, or other processing lowering the susceptibility of the sludge to putrification and eliminating hazards to the environment and human health,
- Subjecting the sludge to testing in terms of meeting defined sanitary standards, and
- Conducting tests with respect to heavy metal content in line with regulations.

Dosages of sewage sludge as used are established separately for each batch, taking into account the type of soil on which it is to be used, its manner of usage, plant phosphorus and nitrogen demand, and sludge quality. Dosage levels are defined by the directive in line with their purpose (e.g. agriculture, land recultivation, growth of plants for composting).

Table 1. Allowable dosages of municipal sewage sludge

Usage of Municipal Sewage Sludge	Dosages of Municipal Sewage Sludge (tones of dry weight)	Remarks
• Agriculture • Reclamation of land for agricultural purposes	3 t d.w. ha^{-1} $year^{-1}$	Cumulative dose should not exceed 6 t d.w. ha^{-1} 2 $year^{-1}$ 9 t d.w. ha^{-1} 3 $year^{-1}$
• Reclamation of land for other purposes • Cultivation of plants intended for compost production • Cultivation of plants not intended for human consumption and animal feed	15 t d.w. ha^{-1} $year^{-1}$	Cumulative dose should not exceed 30 t d.w. ha^{-1} 2 $year^{-1}$ 45 t d.w. ha^{-1} 3 $year^{-1}$

Source: Regulation of the Minister of Environment of 13 July 2010 on the municipal sewage sludge (OJ 2010r. No. 137, item. 924).

Soil tests are performed (reference methods) prior to using sludge in agriculture. These include testing the soil acidity (pH), heavy metal content, and available phosphorus content (P_2O_5 mg/100 g of soil). The acidity of the soil designated for the use of sludge cannot be lower than pH = 5.6 and the heavy metal content in the soil should be in agreement with the directive.

In order to safeguard the natural environment against the application of inappropriate sludge to the soil, the sewage sludge producer is obligated to:

- Subject the municipal sewage sludge to testing,
- Perform tests on the soil for heavy metal content prior to using the sludge on it,
- Provide the owner, tenant, or other person managing the property with the test results (sludge and soil) as well as with information relating to dosages of the sludge that may be used on various soils, and
- The owner, tenant, or other person managing the property on which municipal sewage sludge is used is obligated to store documents relating to sludge and soil test results as well as information regarding sludge dosages used for a period of five years.

The sewage sludge producer is bound to complete a sludge transfer and receipt card (Journal of Laws 2010, No. 249, item 1673) containing the address and signature of the farmer receiving the sludge during supply of the product. This document is kept by the producer as proof of the transfer of the sludge. The producer is obligated to maintain records of municipal sewage sludge in line with the new card (Journal of Laws 2010, No. 249, item 1673).

The producer of plants using sewage sludge should have a copy of the analyses of test results relating to the soil (pursuant to the directive) on which the tested sludge was used, the document relating to the chemical composition of the sewage sludge, and information on dosages as defined by the producer, in line with the provisions of the directive. The farmer should also keep the test results (sludge/soil) for a period of five years and observe the above–specified interdictions. The described documents should be from the sludge producer. The farmer has the right to demand the above–specified documents and may refuse acceptance of the sludge if they are not provided. Inspections were conducted on farms throughout Poland over the years 2009–2010. Uncovered shortcomings included failure to observe sludge dosages as stemming from the provisions of the directive as well as failure to conduct soil tests prior to the application of sludge. Legal penalties may be applied for failure to adhere to the directive.

Pursuant to the Directive of the Minister of Environment, sewage sludge cannot be used on land where fruit plants (this does not apply to orchards) and vegetables are grown, that are used for growing under covers or designated for growing berry bearing plants and vegetables, where the edible portions are in direct contact with the soil (within ten months preceding harvesting or during harvesting) and are eaten raw. This ban also encompasses very permeable soil, i.e. loose and weakly clayey sands as well as light clayey sands if the water table is at a depth of less than 1.5 m below grade level as well as in areas used as pastures and meadows, terrain with a slope greater than 10%, and soils designated for the production of plants consumed directly by people. The prohibition further includes flood plains, lands temporarily flooded and swampland as well as areas temporarily frozen, snow covered, and the strip of land of a width of 50 m directly adjacent to the shores of lakes and channels. Sludge cannot be used on land located within a distance of less than 100 m from water sources, dwellings, and food production plants. The ban is also effective in areas of protected inland water reservoirs (if acts of local law do not state differently – Article 58 of the Water Code), and on land subject to indirect protection of water source zones (if acts of local law do not state differently – Article 58 of the Water Code).

Successive regulations are found in the Directive of the Minister of Environment (Point II, items 13–21 of the Attachment to the Directive of the Minister of Environment on the R10 Recuperation Process, Journal of Laws 2007, No. 228, item 1685) on sludge and slurry from industrial sewage treatment plants that may be used for fertilizing or improving the soil by their application to the soil surface, assuming the meeting of all requirements as defined in this directive.

4. Rational use of sewage sludge in sustainable environmentally–friendly intensification of bioenergy crops

The recycling of sewage sludge is one of the most important challenges facing wastewater management in Poland and other countries of the European Union (Tchobanoglous et al 2004). Domestic sewage treatment plants provided services for only 66% of the population (89% in cities, and only 31% in rural areas, which are home to approximately 39% of the population – temporary data) in 2911. Seven cities were not served by sewage treatment plants in that same year. Approximately 15% of industrial facilities had no sewage treatment plants and dumped their sewage directly into waters or the earth. Modern sewage treatment plants, with high–level biogene removal, serve only 497 towns and cities and 630 rural municipalities in Poland. These facilities treated 1,013 hm^3 of sewage effluent, which is 80% of the effluent delivered by the urban and rural sewage systems (Concise statistical yearbook of Poland 2012).

To date, one of the most popular methods of recycling is the use of municipal sewage sludge as a fertilizer component containing many valuable ingredients in the form of micro– and macro–elements vital to the growth and development of plants. Agricultural use means that basic components such as phosphorus and nitrogen for plants as well as other nutrients and organic substances contained in the sludge are introduced into the soil to improve it and may replace traditional chemical fertilizers. It is in this context that there is an urgent need to apply a safe path for the utilization of sewage sludge. It is assumed that in the future the agricultural use of sewage sludge shall be one of the recycling options in addition to combustion. Combustion facilitates the generation of thermal energy and electricity. However, its downside is the loss of nutrients contained in the sludge, including phosphorus, which is a vital nutrient for living organisms. Many of the world's experts have proposed the recovery of phosphorus mass from sewage on a level of 75%. This strategy has led to the development of new technologies for the processing of sludge, taking into account the recovery of phosphorus and the heavy metals it contains. Two technologies have been proposed in Sweden—bio–Con and Cambi–KREPRO, They are presently in their implementation phases. They shall be encompassed by cost and environmental impact assessment. Both technologies use sulfuric acid to dissolve the phosphorus, which is successively recovered and used as fertilizer.

The volume of municipal sewage sludge being produced has been growing recently. Data from the National Waste Management Program (KPGO) show that there will be a systematic increased in the quantity of sewage sludge from municipal sewage treatment plants in the upcoming years. By the year 2014 it should reach over 700,000 Mg (KPGO, *Polish Monitor*, No. 11, 2003). Growth in sludge mass shall certainly continue until such a time as Poland builds a sufficient quantity of sewage treatment facilities capable of serving all wastewater producers.

The trend in sludge management noted in Poland is essentially similar to the one formed in the countries of Western Europe. Recent years have seen the taking on of importance of methods allowing for diversified recycling of sludge, especially including nature–oriented use. There is a backing away from the depositing of sludge in dumps or its sinking in the sea. Thermal methods for utilizing sewage sludge are also gaining in importance. Additional sanitation using calcium compounds is sometimes necessary in order to fully and positively sanitize sludge after aerobic stabilization. In addition to its bactericidal effect, calcium in the form of CaO results in a decrease in organic substances, decreased water content, and decreased metal mobility (Baran and Turski 1999; Krzywy 1999, Romanowska-Duda et al 2007).

Sewage sludge is characterized by significant variety in physical properties and chemical composition that are dependent on sewage effluent properties and treatment and processing technologies. The fertilization properties of sludge are characterized by significant content of organic substances, nitrogen, phosphorus, calcium, magnesium, sulfur, and a quantity of valuable micro–elements, including cobalt, copper, nickel, and zinc. Also valuable are the organic substances maintaining the structure of the soil and influencing its water, thermal, and sorbent properties as well as biological life. Undesirable sludge components that may limit its use in nature are heavy metals and pathogens (Bojarowska et al. 1982; Siuta 1988; 1997, 1998). Studies to date show that in most cases the content of heavy metals is within allowable limits (Bernacki and Pawłowska 1994, 1996).

Not without significance is the C:N ratio in the sludge, which is in the 5.7–16.7:1 range (Krzywy and Iżewska 2004). This guarantees that in using sludge as a fertilizer, the nitrogen it contains will not be subject to biological sorption. At the same time, humification processes involving the organic matter introduced into the soil with the sludge will proceed properly. Compared with manure and liquid manure, sludge contains significantly more nitrogen and phosphorus as well as calcium and magnesium. The fertilization value of sludge is ranked as being more favorable as compared with manure or mineral fertilizers (Gorlach and Mazur 2002).

5. Potential use of biomass for energy

In Poland, the acquiring of energy from biomass has significant advantages over other renewable energy source technologies because of the potential for growing energy crops on marginal (poor) soils. However, this very promising market is, to a great extent, undeveloped. Thus, there is a lot of space facilitating the intensification of biomass production for energy goals that is environmentally friendly through the use of new agro–technologies for the growing of energy crops while simultaneously monitoring environmental bio–indicators in order to protect natural resources (Grzesik and Romanowska-Duda 2009a, Grzesik et al 2011a, b).

Biomass derived from energy crops has already proved itself as being technically feasible and cost effective in the production of renewable energy. Success is dependent on such factors as the regular supply of this plant raw material. A properly and sustainably managed energy economy should create buffer stores and build a greater and more diverse biomass sector on a global scale. At the same time, steps should be taken to improve logistics, which will make it possible for companies to produce energy at competitive prices. Increasing the supply of biomass requires the application of modern agro–technology using environmentally–friendly bio–stimulators, organic municipal products, the use of poor, undeveloped soils that are not appropriate for food production, and the improvement and development of the currently weak logistics behind the delivery of the plant raw materials in the Łódź region as well as the country as a whole (Grzesik et al. 2009).

The use of biomass in power engineering and combined electricity and heat generating plants in Europe is on the rise. The enormous energy potential resting in biomass is stirring the interest of global companies. Among examples is the energy giant GDF Suez, which uses various types of biomass in the combustion process in its eight electricity generating plants in Belgium, the Netherlands, Poland, and Brazil. Each of these countries can receive emission credits in line with the provisions of the Kioto Protocol. GDF Suez has declared that it will build the world's largest energy–generating block using biomass in Poland. It will have a rating of 190 MW and be capable of supplying over 400,000 households.

The demand for biomass has grown recently. With its existing potential and the sustainable management of farmland, Poland can become a powerhouse in its production in Europe. According to the Institute of Soil Science and Plant Cultivation (IUNG) of Puławy, Poland has at its disposal an area of over 600,000 ha that can be dedicated to energy crop plantations and is capable of producing over 10,000,000 tons of biomass per annum, which can generate a revenue in the area of PLN 2.5–3.0 billion creating a new direction in industry—agrofuel. This venture will significantly improve Poland's chances of meeting its obligation to produce 15% of its energy from renewable sources by the year 2020.

In the Voivodeship of Łódź, a typical agricultural voivodeship that can serve as an example in the development of renewable energy in Poland, energy crop plantations currently occupy over 300 ha and available total biomass (originating from not only the energy plantations) is estimated at approximately 18,000 tons. At the same time, current demand for biomass amounts to at least 60,000 tons. Expectations are that within three to five years, this demand must grow to at least 100,000 tons, which is six times more than today. Assuming that the average output of an energy willow plantation (starting with the third–year harvest) amounts to approximately eleven tons per hectare, achieving a planned amount of 100,000 tons requires approximately 10,000 hectares for planting. Fallow and set–aside land (Grades V–VI) in the Voivodeship of Łódź currently accounts for 123,887 ha (11% of arable land). Grains will have to be grown on a part of this fallow and set–aside land—that with for favorable conditions—as a deficit is beginning to appear in the voivodeship. Energy crops should be grown on the remaining fallow and set–aside land with soils of the lowest quality. In order to prevent the monoculture cultivation of energy crops, plant species biodiversity should be applied, where the plants should be adapted to specific environmental conditions. The main structures taking part in implementing the production of biomass for energy will be small– and large–area farmers, power engineering companies, local government, and sewage treatment plants that, thanks to developed technologies, will be able to provide produced sludge to farmers (instead of costly and hazardous storage) for nature–oriented use in the production of energy crops. Currently, in connection with the growing demand for biomass, the price achieved for energy produced from it is coming dangerously close to the price of energy produced using coal dust. Possibilities for lowering it include increased yields per unit area and decreased costs of biomass production. This goal is served by the development of economical technologies that use free sludge from municipal sewage treatment plants and lagoons instead of costly artificial fertilizers that additionally contributes to environmental pollution. The developed technologies can be used in Poland and Europe. They are related to the latest trends in the production of biomass for energy purposes. The research to date of the authors of this paper indicates the potential for significantly increasing biomass by using low–quality soils. This will play a role in improving the energy security of Poland as well as an increase in the living standard of energy crop producers and in the efficiency of acquiring renewable energy by power engineering companies. At the same time, this solves the very serious problem of storing municipal sludge. This venture as well as the development of technology acts to accelerate the rate of innovativeness throughout the whole of the value chain creating ecological sustainability in the product life cycles and technological processes, while opening up new possibilities in the service sector. Such progress is a locomotive for development and the creation of jobs. Government support is vital on a national and global level in order to manage this gargantuan task, as is the development and perfecting of new and efficient technologies for acquiring renewable energy, including from biomass. It is assumed that in the long–term the technologies for producing renewable energy will, to a great extent, replace traditional ways of producing energy from fossil fuels. This tendency is already underway and there is no retreat.

6. Economic prognoses for the use of sewage sludge in the countries of Europe

Use of bioenergy in the countries of Europe will grow in the nearest future in order to meet requirements for producing renewable energy as directed by the European Union. Biomass of energy plant produced on a greater scale will play a major role in the growth of energy production (EEA 2006). The short rotation system (SRC) for producing biomass for the generation of heat or electricity, or both, has been identified as the most energy–saving technology for conversion from coal in order to decrease greenhouse gas emissions (Styles and Jones 2007). It is for this reason that it is considered a promising way to satisfy European demand for energy using renewable sources and increasing energy security.

SRC refers to biomass production and cultivation management systems, including agro–technology involving the preparing of the soil, fighting weeds, planting plants, fertilization, harvesting, etc. Bioenergy systems must be land–efficient and should bring about an increase in the amount of energy produced per hectare. Such systemic cultivation is more cost–effective than in case of traditional farming. It is also economically attractive, which has an impact on encouraging and coaxing farmers to cultivate bioenergy plants (Berndes et al. 2008, Ericsson et al. 2009). One way is application of wastes, including sewage effluent and sludge, to energy plantations. This method has been acknowledged as one of the most attractive ways of achieving environmental and energy goals, while simultaneously increasing farmer incomes (Dimitriou and Aronsson 2005).

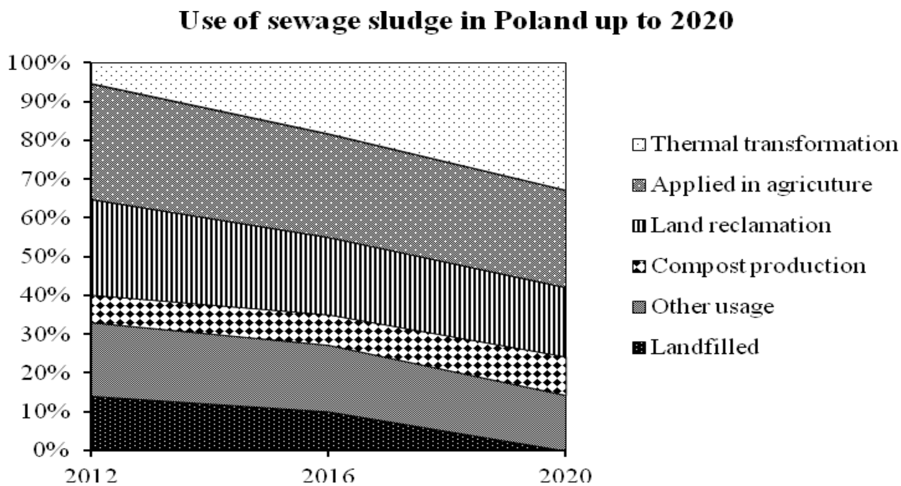
According to Central Statistical Office (GUS) projections, the quantity of thermally utilized sludge will increase up to the year 2014, as will the quantity of stored sludge. The application of sludge for the production of plants designated for composting will also increase.

Table 2. Total sewage sludge (thousands of tons of dry matter) from municipal wastewater treatment plant generated during the year in Poland and their use (application in agriculture, application in land reclamation including reclamation of land for agricultural purposes, thermal transformation, application in cultivation of plants intended for compost production, landfilled and other usage)

	Year				
	2000	2005	2008	2009	2010
Total	359,8	486,1	567,3	563,1	526,7
Applied in	-	66	112	123,1	109,3
Land	-	120,6	105,8	77,8	54,3
Compost	25,5	27,4	27,5	23,5	30,9
Thermal	5,9	6,2	6	8,9	19,8
Landfilled	151,6	150,7	91,6	81,6	58,9
Other usage	176,8	115,2	224,4	248,2	253,5

Source: based on Environment (2011) CSO, Regional and Environmental Surveys Division ISSN 0867-3217.

Figure 1. Projections for sewage sludge use in Poland up to 2020



Source: Grabowski Z. (2011), *Termiczne przekształcanie osadów ściekowych na przykładzie STUO w Krakowie,* IV Forum Gospodarka osadami ściekowymi, Warsaw.

There is a big demand on the domestic market as well as in the Voivodeship of Łódź for modern, cost–effective plant production technologies, including energy crops for poor and degraded soils where plants are not cultivated for food. Energy crop production, even on medium–quality soils (Cultivation Grades III–IV), has been unprofitable or barely profitable to date in comparison with gardening. In the case of poor soils (Cultivation Grades V–VI), such production mostly results in losses and, for this reason, is not undertaken.

The application of sewage sludge makes the production of energy crops profitable on poor soils, has a positive impact on the environment, does not compete with food production, makes possible the development of land that has not as of yet been used agriculturally or land of low productivity, and expands the job market for people living in the area (Cogaliastro et al 2001).

The economics trump cards of introducing this technology are obvious on a national scale. In just the Voivodeship of Łódź, a typical agricultural region, the benefits of applying renewable technologies include:

- The introduction of many species of plants for use for a multitude of direction and a capacity to grow them on low–quality soils (including Cultivation Grades V–VI, which account for 17.71% of the arable land in voivodeship and whose surface area amounts to 170,000 ha). Most of the proposed species, except for those designated for the acquisition of energy, can be used as animal feed, including as silage. Moreover, these plants clean the soil of toxic contamination and some have additional utilitarian qualities.

- The development of low–quality soils where no agricultural production is conducted or production is minimal, which results in growth of the job market and a decrease in unemployment.
- The nature–oriented management of sludge from municipal sewage treatment plants, the storage of which is costly and hazardous to the environment. In the Voivodeship of Łódź alone, the nature–oriented use of sludge by energy plantations may bring the utilities at least PLN 60 million in savings, assuming that the sewage treatment plants add PLN 100 to each ton of supplied sludge certified for nature–oriented use, where one hectare of plantation needs fifty tons of sludge as fertilizer, where energy crops in the voivodeship should encompass approximately 34,000 ha (20% of Grade V and VI soils) in the nearest future. It is assumed that on a national scale, energy crops shall be grown on two, or perhaps even four million hectares, i.e. 20% of the whole of arable land (Tytko 2009). An additional trump card is the decrease in very costly sludge ingredients.
- The decrease in outlay for artificial fertilizer and chemical plant protection products, and improved environmental conditions. Plantation owners in the Voivodeship of Łódź cultivating energy crops over an area of 34,000 ha have the potential to save at least PLN 24 million per annum as a result of the decrease in the cost of mineral fertilization, assuming that basic fertilization using mineral fertilizer that is detrimental to the environment costs only PLN 1,000/ha.
- The justifiability of using sewage sludge in the systemic cultivation of energy crops has been investigated in several countries in Europe, where it was deemed an inexpensive alternative method to fertilization using chemical fertilizer (Aronsson and Perttu, 2001). Numerous study results indicate the major potential in applying sewage sludge and effluent in order to increase the profitability of energy crop cultivation by decreasing the costs of fertilization and increasing the production of biomass (Dimitriou and Rosenqvist 2011, Grzesik et al. 2007, Grzesik and Romanowska-Duda. 2009b,c).

Table 3. Theoretical Estimates of Land Required if All Available Sewage Sludge (ss) and Wastewater (ww) Is Applied to SRC, and Resultant Increases in Renewable Energy in Various EU Countries

	Population (Millions)	SRC area to be fertilised with all available ss (t ha)	SRC area to be fertilised with all available ww (t ha)	Arable land surface with SRC fertilised with ss (%)	Arable land surface with SRC fertilised with ww (%)	Energy produced from SRC if all ss applied (PJ)	Energy produced from SRC if all ww applied (PJ)
EU27	495.13	35673	1505	34	1.4	5636.3	309.2
Czech Rep.	10.29	824	34	32	1.3	117.1	6.4
Estonia	1.34	107	4	17	0.7	15.3	0.8
Finland	5.28	422	17	19	0.8	60.1	3.3
Germany	82.31	5931	250	50	2.1	937.0	51.4
Hungary	10.07	604	25	17	0.7	114.6	6.3
Latvia	2.28	183	8	16	0.7	26	1.4
Lithuania	3.38	271	11	15	0.6	38.5	2.1
Poland	38.13	3052	116	26	1	434	23.8
Romania	21.57	1295	53	15	0.6	245.5	13.5
Slovakia	5.39	486	19	37	1.5	61.4	3.4
Slovenia	2.01	161	7	93	3.8	22.9	1.3
Sweden	9.11	505	23	19	0.9	103.7	5.7

Source: Dimitriou, I., Rosenqvist, H. (2011), Sewage sludge and wastewater fertilisation of Short Rotation Coppice (SRC) for increased bioenergy production - biological and economic potential "Biomass and Bioenergy" 35(2): 835-842.

7. Conclusions

The required increase in energy production using biomass, a basic source of renewable energy, requires the application of new, highly–efficient, and less costly plant production technologies that are not in competition with food production. Certified sewage sludge, the storage of which is challenging, costly, and very hazardous to the environment, may be used in the production of biomass for energy on poor soils where plants for consumption are not cultivated. Their use decreases the costs of energy crop production, improves properties and biological life in the soil, and significantly increases biomass yields.

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Streszczenie

BIOLOGICZNE I EKONOMICZNE UWARUNKOWANIA ZASTOSOWANIA OSADÓW ŚCIEKOWYCH W PRODUKCJI BIOMASY ROŚLINNEJ NA CELE ENERGETYCZNE

Celem artykułu jest przedstawienie prawnych, biologicznych i ekonomicznych uwarunkowań produkcji energii z biomasy roślinnej, ze szczególnym uwzględnieniem zastosowania osadów ściekowych mających certyfikat przyrodniczego wykorzystania w rolnictwie. Zwiększenie produkcji biomasy wymaga wprowadzenia tanich i wysokowydajnych technologii produkcji roślin przyjaznych środowisku. Zastosowanie certyfikowanych osadów ściekowych zwiększa efektywność ekonomiczną upraw energetycznych i korzystnie wpływa na środowisko.

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European Union Water Policy: Key Issues and Challenges

Abstract

Water resources are among the most valuable resources of the natural environment. The sustainable and integrated management of these resources is the basis of European water policy. Pursuant to the Water Framework Directive, all waters in the European Union should achieve a state considered at least good by the year 2015. Just how this objective can be met continues to be a topic of discussions in some of the Member States. There exist serious problems and delays in performing and implementing the provisions of the Directive in most EU countries. What is more, the state of the water economy in several countries, including Poland, has been criticized by the European Commission. Many challenges stand before European water policy. They require solutions on a global and local level. This article presents current key problems and planned directions for EU water policy development, subjected to analysis and assessment. Note is taken on the newest initiative of the European Commission in the area of water policy, especially the plan for protecting Europe's water resources—the Blueprint to Safeguard Europe's Water Resources.

1. Introduction

Water is a vital resource and prerequisite for human, animal, and plant life as well as an indispensable resource for the economy. It also plays a fundamental role in the climate regulation cycle. Human activity is having an enormous impact on water resources. Taking this into account, we need to

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protect water resources, manage water according to principles of sustainable development, and implement integrated water policy in the EU.

Protection of water resources, of fresh– and salt–water ecosystems, and of the water we drink and bathe in is therefore one of the cornerstones of environmental protection in Europe. The stakes are high and the issues transcend national boundaries. Concerted action at the EU level is necessary to ensure effective protection.

Water is a valuable resource that we must use properly and sparingly, making sure that we have enough for all of its uses, while avoiding polluting our rivers, seas, and oceans. Among all other natural resources, this is one of the most vital ones for our continued existence on this planet.

The Water Framework Directive (WFD)[1], which came into force in the year 2000, provides a framework for Member States to manage water resources in river basin districts across the European Union in an integrated way. All Member States have undertaken the commitment to protect and restore all bodies of ground and surface water (rivers, lakes, canals, and coastal water) so that all river basin districts achieve "good status"[2] by 2015 at the latest.

The 1st cycle of the WFD shows clear success stories, e.g. integration of the environmental perspective into water management, enhancement of international cooperation, public and stakeholder participation, growth in the knowledge base, and improvement of chemical water quality. However, we can see a long road ahead to meet the ambitious objectives of European water policy as well.

There are many problems in the water economy and sustainable management of water resources in Europe. The majority of Europeans are worried about both water quantity and quality A recent European Commission survey shows that seven out of ten Europeans think that water–related problems are a serious concern[3]. Pollution from point and diffuse sources, over–abstraction of water, and alterations to rivers and lakes threaten efforts to achieve a good status for European waters by 2015. Moreover, droughts, floods, and chemical pollution are seen as significant challenges. Therefore, we need an integrated approach to the future of water resources in Europe. The various

[1] Directive 2000/60/EC establishing a framework for Community action in the field of water policy.

[2] "Good status" means both "good ecological status" and "good chemical status." Read more at http://www.eea.europa.eu/soer/europe/water-resources-quantity-and-flows

[3] European Commission (2012), *Attitudes of Europeans Towards Water – Related Issues*, Flash Eurobarometer, March 2012, http://ec.europa.eu/public_opinion/flash/fl_344_sum_en.pdf

European Union policies must be coordinated for the protection of water[4]. There is a need to maximize Europe's water–saving potential, where innovation and research can play a fundamental role in this respect. Water–related natural disasters such as droughts and floods have become more frequent and severe over large parts of our continent. Their severity and frequency is expected to increase as a result of climate change and changes in land use.

Water issues will all be considered by the European Commission in its new document—the "Blueprint to Safeguard Europe's Water Resources"—planned for November 2012. The Blueprint will identify current gaps and future priorities. It will propose measures to steer water policy development until 2020. It will be based on an analysis that integrates economic and climate modelling in the period up to 2050.

2. Setting the Scene in Water Policy and Management

According to the European Commission, more than 50% of European surface water bodies have less than good ecological status and the environmental objectives of the Water Framework Directive for 2015 will not be fully met[5]. The status of groundwater is also worrying. The main challenges in this context are in agriculture, climate change, hydromorphological pressure, and systemic challenges. Furthermore, a significant proportion of EU basins are currently scarce of water and this proportion will increase by 2030. Some measures are being implemented, but these will not be able to reverse the trend in the near future.

Freshwater resources are of major environmental and economic importance. Their distribution varies widely among and within countries. In arid regions, freshwater resources may at times be limited to an extent such that demand for water can be met only by going beyond sustainable use, leading to reductions in terms of freshwater quantity.

Access to good quality water in sufficient quantity is fundamental to the daily lives of every human being and to most economic activities. Water scarcity and droughts have now emerged as a major challenge and climate change is expected to make matters worse. This is a worldwide problem. The European Union has not been spared. Water scarcity and droughts are not just a matter of

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[4] Environment Council – informal meeting: *Europe Needs an Integrated Water Policy,* March 2011, Budapest, http://www.eu2011.hu/news/europe-needs-integrated-water-policy

[5] European Commission (2012), *3rd European Water Conference, Summary Report*, Brussels, http://waterblueprint2012.eu/conference-documentation

concern for water managers. They have a direct impact on citizens and economic sectors that use and depend on water—agriculture, tourism, industry, energy, and transport. In particular, hydropower heavily depends on water availability. Water scarcity and droughts have broader impacts on natural resources at large through negative side–effects on biodiversity, water quality, increased risks of forest fires, and soil impoverishment as well.

Existing European and national assessment and monitoring programmes on water scarcity and droughts are neither integrated nor complete. Filling knowledge gaps and ensuring data comparability across the EU is now a big problem. In this context, research has a significant role to play in providing knowledge and support for water policy making.

Freshwater abstractions, particularly for public water supplies, irrigation, industrial processes, and the cooling of electric power plants, exert major pressure on water resources, with significant implications for their quantity and quality. Main concerns relate to the inefficient use of water and to its environmental and socio–economic consequences—low river flows, water shortages, salinization of freshwater bodies in coastal areas, human health problems, loss of wetlands, desertification, and reduced food production.

Europe continues to waste at least 20% of its water due to inefficiency (*Ecologic* 2007). The potential for water efficiency is not exploited to the fullest extent in the EU. Even though they are cost–effective, a number of measures are not taken owing to unaffordability. Integration achievements at EU, national, and regional levels vary widely from one sector to another. In general terms, there is a lack of consistency and, in some cases, even counter–productive effects on water resource protection.

To address the problem of illegal water abstraction, river basin authorities and managers need more leverage in identifying illegal abstraction and penalizing it. Compliance mechanisms applicable to all river basins are needed. In some parts of Europe, the rigidity of the water concession system is still a major problem, limiting the ability of river basin authorities to register the amount of water that is abstracted.

The subject of water and food security is part of a broader nexus between water, energy, and food. While food production is based on the availability of clean water, it also has considerable impact on water quality and quantity. For this reason it has to be sustainable if it does not want to be self–defeating. Similarly, energy production involves considerable quantities of water and may negatively impact on water quality. Finally, water transport, provision, and treatment require considerable amounts of energy. It is therefore essential to develop integrated sustainable policies that make coherent choices in these three fields. This is all the more necessary as worldwide water availability cannot be taken for granted. Unfortunately, we are witnessing extremely serious droughts in 2012 in many parts of the world, notably the United States, but also in Southern and Eastern Europe (Potočnik 2012b).

Since its adoption, the WFD has been the main driver for improvement in governance in European water management. Public participation, cross–border cooperation, and the knowledge base have improved. The implementation of water policy has sometimes been difficult due to a fragmentation of institutions. Taking cooperation and coordination to a higher level requires the defining of common objectives.

Of importance is the fact that currently Member States have difficulty in implementing cross–sectorial activities between the WFD and other sectors. This is because water policy makers have no jurisdiction to intervene in other sectors such as agriculture and energy. Moreover, coordination between water quality and hydromorphological aspects as well as between water policy and nature protection has so far not been sufficient. Cooperation between the water and agricultural sector is where governance is most deficient. This is mainly due to the difficulty in setting up a dialogue and because of the system of subsidies in the agricultural sector. Political will is needed to push further cooperation between the Common Agricultural Policy (CAP) and the WFD.

Extensive consultations on Water Framework Directive River Basin Management Plans (RBMP) have been available since 22 December 2009 in all River Basin Districts across the EU. The deadline for publishing and the deadline for reporting these plans to the Commission has expired (22 March 2010). However, there were serious delays in Spain, Belgium and Greece in 2012, where the RBMP have not yet been developed (consultation has not started or is on–going). In Portugal, consultations have been finalised, but are waiting for adoption. In other EU countries, River Basin Management Plans have been adopted[6].

Article 8 of the EU's Water Framework Directive obliges Member States to gauge the health of their surface and groundwater by way of national monitoring programmes. This way the status of the waters can be established and any corrective measures can be properly targeted. For example, Poland has as of 2012 not complied with EU legislation on water protection, including the monitoring of water quality[7]. Thus, the European Commission sent an additional reasoned opinion asking Poland to implement the Directive correctly. Poland's

[6] Read more: http://ec.europa.eu/environment/water/participation/map_mc/map.htm

[7] European Commission (2012), *EU law: Commission acts to ensure that European legislation is fully and properly implemented*, MEMO/12/134, 27/02/2012: http://europa.eu/rapid/searchResultAction.do

deadline for transposing the Directive expired in May 2004. However, at that time it had not yet adopted laws to meet the Directive's requirements in a number of areas, including water quality monitoring.

Unfortunately, this is not the only infringement procedure against Poland instituted by the European Commission with respect to poor water management. Separate proceedings have also been launched in the matter of work referred to as "maintaining rivers and restoring flood damage" in the Podlaskie Voivodeship. At the same time, charges of breaking EU law in connection with the water economy were filed against Poland in March 2012. The claims relate to the maintaining of rivers in a way that causes damage to their nature values as well as without any environmental impact assessments. The Commission is of the view that work conducted on Polish rivers under the heading of "maintenance" is not restricted to maintenance, but also often results in the permanent modification of the riverbed and its riverbank zone. Pursuant to European Union law, such transformations necessitate a prior environmental impact assessment as well as an assessment regarding Natura 2000 areas. This is not done in Poland.

According to the current assessment of the European Commission, the problem behind water management and flood control in Poland rests with the fact that it is based on antiquated solutions that often forget that a river is a living ecosystem. Many of the actions taken, such as the hydrotechnical encasing of rivers, the simplified shaping of channel cross–sections, and increasing the throughput of riverbeds and the areas between levees, do not bring the assumed effects. Usually, they increase the flood hazard and destroy the valuable natural environment of the rivers, their valleys, and lead to the drying of wetlands. The European Commission also charges that Poland, in planning projects relating to water management, often ignores environmental impact assessment procedures.

In 2011 the European Commission was asking the public for its views on the most appropriate actions to improve water management in Europe. The poor assessment of water management as implemented not only in Poland, but in many EU countries, has been issued by not only the European Commission, but by the citizens themselves. According to a Eurobarometer survey published by the EC on 22 March 2012[8], close to three–quarters of Europeans think that the EU should propose additional measures to address water problems in Europe. This survey was carried out in all twenty–seven Member States of the European

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8 European Commission (2012), *Environment: Europeans Call for Stronger EU Action on Water*, IP/12/289, 22/03/2012, Brussels, http://europa.eu/rapid/pressReleasesAction.do?reference=IP/12/289&format=HTML&aged=0&language=EN&guiLanguage=en

Union in March 2012. Some 25,524 respondents from different social and demographic groups were interviewed in their mother tongue on behalf of the European Commission.

A sizeable majority (68%) of Europeans think that water–related problems are serious. Droughts are a greater concern in the Mediterranean countries. Floods are seen by a large majority of Europeans (79 %) as a serious problem. A total of 61% of interviewees felt that they were not doing enough to protect water resources, but they also think that more efforts are needed on the part of industry, agriculture, and energy producers. When asked about solutions to the water challenges, 67% of Europeans are of the view that providing more information on the environmental consequences of water use would be most helpful. They see awareness–raising as the most effective means of reducing water–related problems. Indeed, even though citizens are taking small individual actions to save and protect water, including limiting the amounts used or using less pesticide in their gardens, a majority of 61% feel they are not doing enough to protect our water resources.

Citizens wish to do more to protect water resources and to be better informed in order to do so. However, to tackle these water issues, Europeans ask for the introduction of heavier fines for polluters, a fairer pricing policy, and financial incentives (tax breaks or subsidies) as well. A majority support water pricing based on volumetric use. They agree that prices should increase as environmental impact grows.

A total of 73% of Europeans think that the EU should propose additional measures to address water problems in Europe. This trend is confirmed all over the continent as the majority of citizens in all Member States think this issue should be addressed at the EU level. Europeans are of the view that the main focus of such measures should be on water pollution from industry, agriculture, the overuse of water, floods, and droughts[9].

3. Challenges for the Future

Analysis of recently published legal acts, documents, official press releases of the European Union as well as articles make it possible to formulate several key challenges and directions of action in the area of EU water policy and management up to the year 2030. These are presented below.

[9] Ibid.

First place involves the creation of economic incentives fostering more efficient management of water resources. Economic instruments will only work if the necessary background data (e.g. information on environmental flows) and preconditions (e.g. abstraction licenses) are present. Mandatory metering is needed for the implementation of water pricing policies in Europe. In spite of the WFD's specific requirements (Article 9), economic instruments have not been widely used by Member States thus far. Pricing policies that may appear to be very well designed can prove totally ineffective if most water abstraction is neither metered nor registered by the authorities. The WFD (Article 11) requires the implementation of systematic control over water abstraction. Illegal water abstractions need to be controlled.

The putting the right price tag on water is a very important issue. Water pricing needs to be implemented in combination with other policy tools. Regarding the application of social water tariffs, the EC has argued that everybody should pay the same price for their water use. This would ensure consistency. Governments can use other policy tools to support low–income groups. Water pricing should be accompanied by education and awareness–raising related to water demand management. There is a need to strengthen the application of a "polluter pays" principle. For example, remediation costs are not borne by the polluter at present. According to a recent OECD report[10], these costs are very significant.

Progressing towards full implementation of the Water Framework Directive is a priority in order to address mismanagement of water resources. This issue is often a result of ineffective water pricing policies that generally do not reflect the level of sensitivity to water resources at local level. The "user pays" principle is hardly implemented beyond the sectors of drinking water supply and wastewater treatment. Introducing this principle at the EU level would put an end to needless losses or waste, ensuring that water remains available for essential uses across Europe, including all parts of cross–border river basins. In other words, it would encourage efficient water use.

The next challenge is allocating water and water–related funding more efficiently—improving land–use planning and financing water efficiency. Land–use planning is one of the main drivers of water use. Inadequate water allocation among economic sectors results in imbalances between water needs and existing water resources. There is a need to impose conditions on the use of EU funds (Rural Development, Cohesion Policy). A pragmatic shift is required in order to

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[10] OECD (2011), *OECD Factbook 2011–2012, Economic, Environmental and Social Statistics, Water consumption*, OECD Publishing, http://www.oecd-ilibrary.org/economics/oecd-factbook-2011-2012_factbook-2011-en

change policy–making patterns and to move effective land–use planning forward at the appropriate levels.

Drought affected areas are likely to increase in extent. In the face of such circumstances, it has become a European Union priority to devise effective drought risk management strategies. All EU Members States need to develop drought risk management plans, an observatory, and an early warning system on droughts. It is also necessary to optimize the use of the EU Solidarity Fund and European Mechanism for Civil Protection, improving knowledge and data collection, e.g. a water scarcity and drought information system throughout Europe[11].

The EU's policy action on water scarcity and droughts needs to be based on high–quality knowledge and information on the extent of the challenge and projected trends. Existing European and national assessment and monitoring programmes are neither integrated nor complete. Therefore, filling knowledge gaps and ensuring data comparability across the EU is a precondition. In this context, research has a significant role to play in providing knowledge and support for policy making. The challenge of water scarcity and droughts needs to be addressed both as an essential environmental issue and also as a prerequisite for sustainable economic growth in Europe. The existing legal framework in the WFD offers ample room for tackling both water scarcity and droughts through market–based instruments.

Sustainable water policy promotes the formation of a water–saving culture. Further integration of water–related concerns into water–related sectorial policies is paramount in order to move towards this kind of culture. Water saving must become the priority and all possibilities to improve water efficiency must therefore be explored. As the EU seeks to revitalise and reinvigorate its economy and to continue to lead in tackling climate change, the devising of an effective strategy towards water efficiency can make a substantial contribution. In this regard, the fostering water efficient technologies and practices is of great importance.

At present, there are many effective and modern methods of protection against flooding and water management. However, if undertaken actions do not take into account natural conditions, then not only will the risk of floods and droughts as well as damage to property and the environment increase, but there

[11] European Commission (2007), Communication from the Commission to the European Parliament and the Council - Addressing the challenge of water scarcity and droughts in the European Union (COM/2007/0414 final), Brussels: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0414:FIN:EN:PDF

will also be growing losses in agriculture, tourism, and other sectors of the economy dependent on water.

Extreme weather situations trigger extreme hydrologic phenomena (such as floods, inland water, and droughts) more frequently. We must be ready for these situations with green solutions, as opposed to investments in infrastructure. We must understand that floods constitute a part of nature's way. It is not protection against them that we need, but rather co–existence with floods[12].

The Water Framework Directive is Europe's key tool for protecting its waters. The monitoring of surface waters covers the chemical composition of water, a number of key biological elements, and the physical shape of water bodies, in order to provide a comprehensive overview of the health of Europe's waters. Groundwater monitoring programmes will cover water quality and water quantity. For the protection of water ecosystems, there is a need to further promote win–win measures, such as wetland restoration. More attention should also be given to strategic approaches such as green corridor strategies at river basin level.

Another challenge for the future is further action and European regulation on pharmaceutical substances in water. In addition to discussions in the context of the Environmental Quality Standards Directive, further steps should be taken: firstly, implementing stringent legislative criteria, and secondly, looking at ways to reduce pharmaceuticals at source (upstream) and working on hotspot management (e.g. hospital discharges).

Stronger policy integration is needed among water, agricultural, and energy policy as well as key relevant policy reforms (e.g. in the CAP). The European Commission can play a key role in further promoting integration and providing further instruments and practical guidance on the improvement of water management at a local level. It is essential to have a good set of both mandatory and voluntary measures for the agricultural sector. At the same time, we should not rely on regulation only to reinforce policy. Reliable funding (public and private) is fundamental for implementing measures. The objectives of the WFD should be included in cross–compliance requirements under the CAP. Agreements between farmers and water companies are a successful concept and should be further promoted. Water policy also needs a "greener" common agricultural policy or greater emphasis on environment protection in agricultural policy.

[12] European Commission (2007), Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, Brussels: http://ec.europa.eu/environment/water/flood_risk/key_docs.htm

Water policy in the EU should be based on a lucid water hierarchy. Additional water supply infrastructures should be considered as an option when other ways have been exhausted, including effective water pricing policy and cost–effective alternatives. Water uses should also be prioritised: It is clear that public water supply should always be the overriding priority to ensure access to adequate water provision.

Over 90% of the projected population growth by the year 2050 will be in developing countries, often in regions that already are water scarce. In 2030, a half of the world's population will be living in areas of high water stress. Looking towards 2050, according to the OECD[13], there will be increased competition between water users to access water resource. Farmers and the environment will have to compete with cities, energy suppliers, and several industries, to get the water they need. This creates new risks. if any water user does not have access to the volume and quality of water that user needs. Another question is that of trade–offs. How should water be allocated among competing users?

Taking a mix of measures to address European water challenges is critical. The EC expects the need to "unlock" measures that give answers to different problems in a coordinated way, since no single measure will be able to solve the problems at hand.

4. Blueprint to Safeguard Europe's Water Resources

As of the year 2000, EU water policy has made steps to change by taking an integrated approach based on the concept of river basin management aimed at achieving good status for all EU waters by 2015. However, as pointed out by the European Environment Agency's 2010 State of the Environment Report[14] the achievement of EU water policy goals appears far from certain due to a number of old and emerging challenges. The Blueprint to Safeguard Europe's Water will be the EU policy response to these challenges. It will aim to ensure good quality water in sufficient quantities for all legitimate uses.

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[13] OECD (2012), *OECD Environmental Outlook to 2050: The Consequences of Inaction*, OECD Publishing, Paris: http://www.oecd.org/environment/environmentalindicatorsmodellingandoutlooks/oecdenvironmentaloutlookto2050theconsequencesofinaction.htm

[14] EEA (2010), *Synthesis. The 2010 State of the Environment and Outlook Report,* Report No. 1/2010, Copenhagen, http://www.eea.europa.eu/soer/

The time horizon of the Blueprint is 2020 since it is closely related to the EU 2020 Strategy[15] and, in particular, to our planned Resource Efficiency Roadmap[16]. The Blueprint will be the water milestone on that Roadmap. However, the analysis underpinning the Blueprint will cover a longer time span, up to 2050, and will drive our policy for a longer period.

To achieve this ambitious objective, the Blueprint will synthesise policy recommendations building on four on–going assessments[17]:

1. The assessment of the River Basin Management Plans[18] delivered by the Member States under the Water Framework Directive,
2. The review of the EU action on Water Scarcity and Drought[19]
3. The assessment of the vulnerability of water resources to climate change and other man made pressures, and
4. The Fitness Check, which will address the whole of EU water policy in the framework of the Commission Better Regulation approach.

The outputs of these four reviews, together with a large number of studies launched by DG Environment[20], DG Research, the Joint Research Centre, the European Environment Agency (EEA)[21], and others, will provide the knowledge base to develop the policy options that can deliver better implementation, better integration, and completion of EU water policy.

These options will be subject to a thorough impact assessment in order to understand their potential environmental and socio–economic impacts. Action is envisaged in seven specific areas. Focus will be given to land management to see what measures could be widely implemented in the EU and what policy instruments that can accelerate their implementation, in particular water–related green infrastructure measures[22]. In addition to integration of such measures into the Common Agricultural and Cohesion Policies, the European Commission will develop a methodological framework for the wider application of payments for ecosystem services. This is a key tool that is missing that can alleviate the failure

[15] EUROPE 2020,COM(2010)2020 final.

[16] Roadmap to a Resource Efficient Europe, COM(2011) 571 final:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:DKEY=615217:EN:NOT

[17] See more about the Blueprint at website: http://ec.europa.eu/environment/water/blueprint/

[18] http://ec.europa.eu/environment/water/participation/map_mc/map.htm

[19] http://ec.europa.eu/environment/water/quantity/eu_action.htm

[20] DG Environment website at http://ec.europa.eu/dgs/environment/index_en.htm

[21] European Environment Agency (EEA) website at http://eea.europa.eu

[22] Water–related green infrastructure measures mean reforestation, floodplain restoration, soil management, and sustainable urban drainage systems. Read more: EPA website at: http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm

of the market to duly account for such services. Its application can create important economic incentives for water and biodiversity protection.

In the second area, the Blueprint will develop a consistent approach for the internalisation of costs from water use and water pollution. The objective of the Blueprint will be to foster the recovery of environmental costs through the application of a portfolio of economic and communication instruments, complementing regulatory instruments. The options to be developed include criteria for pricing, taxation, removal of harmful subsidies, public procurement, and the setting up of water allocation schemes (including tradable permits) in water scarce areas[23].

At present, the EC does not know the size of the gap in Europe between water demand and water availability in 2020 or 2050. In this respect, the water and ecosystem accounts developed together with the EEA will quantify how much water flows in and out of the river basins. This is the basic essential information that is largely missing today, but which is needed to optimize water use at river basin level and look at alternatives, in particular considering the material and virtual water flows between catchments. On this basis, the Blueprint will tackle water efficiency. It will provide first indications for water efficiency targets at EU level, taking into account the great variety of situations across economic sectors and geographic areas. It will also aim at fostering the development of targets for water efficiency (and quality improvement) in the Member States at sectorial and river basin level. In addition, it will look at ways to improve the water efficiency in both buildings and in distribution networks.

In the next area, the Blueprint will identify the main financial, technological, organisational, and sociological barriers to innovation in the realm of water resource management as well as ways to overcome them. The importance of innovation in the field of water management is recognized by the EU Member States[24]. In 2011, the Council of the European Union invited the Commission to "investigate an innovation partnership on water in close cooperation with the Member States, with a view to achieving sustainable and efficient use of water"[25].

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[23] *Environment for Europeans, Are we doing enough for Europe's waters?,* Magazine of the DG for the Environment, No 47, Brussels, http://ec.europa.eu/environment/news/efe/pdf/efe47/EN-EFE47.pdf

[24] European Commission (2012), *EU Water Initiative,* Annual Report, Brussels: http://www.euwi.net/files/EUWI_AnnualReport_Web.pdf

[25] Council of the European Union Conclusions of 21 June 2011 (doc. 11308/11), *Protection of water resources and integrated sustainable water management in the European Union and beyond - Draft Council conclusions,* http://register.consilium.europa.eu/pdf/en/11/st11/st11308.en11.pdf

Worth mentioning at this point is a valuable European initiative—Water Innovation Europe (WIE). This is an innovation partnership between ACQUEAU[26] and the Water Supply and Sanitation Platform (WssTP), the European Water Platform[27]. It aims to push forward the central initiative of the European water sector—innovative collaboration for sustainable and competitive results through active discussion and debate. Water Innovation Europe 2012, which took place in Brussels in May[28], was a platform for a large number of stakeholders from all background and sectors and from various kinds of organisations and industries to contribute to the on–going drive towards a more innovative and competitive European water sector[29].

The fifth concerns ways for improving the governance system stemming from EU water policy, including the administrative setup and the potential to reduce the administrative burden, while providing the reactive capacity needed to face emerging challenges such as climate change adaptation.

It is also important that the Blueprint will develop options to improve the quality of the knowledge base for water policy making. These could include an improvement of statistical information on the pressures of economic activity on water resources, increased use of satellite and land GMES observations to monitor status and pressures, enhancing the Water Information System for Europe (WISE)[30] to include policy relevant indicators, and developing a roadmap for water research under the next Framework Programme.

Implementation of the Blueprint is also coupled with one of the latest initiatives of the European Commission on water management—the European Innovation Partnership on Water (EIP on Water)[31]. The European Commission envisages the start of implementation of the EIP from early 2013. This

[26]ACQUEAU is an industry driven EUREKA Cluster dedicated to water related technologies and innovation. It aims at promoting innovation and market driven solutions to develop new technologies in the European water sector. The ultimate aim of a EUREKA Cluster is to facilitate the generation of market–driven, pan–European collaborative water research and technological development R&D projects for the benefit of the European Water Industry. Read more: http://www.iwa-pia.org/ and http://www.eurekanetwork.org/acqueau/about

[27] http://www.wsstp.eu/content/default.asp?PageId=688&LanguageId=0

[28] http://www.wsstp.eu/content/default.asp?PageId=944

[29] The water sector and its drive towards innovative development faces challenges that span across various sectors, users, and approaches, such as governance, ICT, water management, communication, agriculture, industry, utilities, private companies providing water services, and other sectors.

[30] WISE is a partnership between the European Commission (DG Environment, Joint Research Centre and Eurostat) and the European Environment Agency, known as “the Group of Four” (Go4). Read more: http://water.europa.eu/

[31] The European Innovation Partnership on Water, COM/2012/216 final.

Partnership is an opportunity to find new solutions to the water challenges we face. It is also a chance for the EU water industry to become more competitive and to translate the ideas of the European water sector into marketable solutions.

Initiative as well as the task facing Europe to engage in the sustainable management of water as a key resource is underlined in the Europe 2020 Resource efficient Europe flagship initiative[32]. The Roadmap to a resource efficient Europe highlights the efficiency gains that can be made. A Blueprint to safeguard Europe's waters is the water milestone on the resource efficiency Roadmap. The Blueprint will present the policy response to the challenges of the implementation issues and gaps related to the current framework of EU water resource management policy. The Blueprint and the EIP on Water will be developed in close coordination to ensure integration of innovative approaches and innovation demand side measures in developing and realizing EU water resource management policy. Furthermore, the EIP on Water will build on the Eco–Innovation Action Plan[33], which focuses on boosting innovation that results in or aims at reducing pressures on the environment and on bridging the gap between innovation and the market. The European Commission supports research to help to manage our water resources sustainably and achieve the shift towards an internationally competitive, water-efficient economy in Europe[34].

As a step in the preparatory process for the Blueprint to Safeguard Europe's Water Resources, the European Commission organised Green Week 2012, the biggest annual conference on European environment policy, which took place from the 22 to 25 May 2012 in Brussels[35]. This year's theme was "Water," under the banner "The Water Challenge – Every Drop Counts." Green Week 2012 presented an overview of water–related EU policies and considered how they should evolve to meet the challenges ahead and to look for solutions to key water problems, like how to safeguard the availability of good quality water against a backdrop of rapid population growth and ever more apparent climate change (Gammeltoft, Buckova 2012).

Green Week also hosted the 3rd European Water Conference[36]- a platform for consultation and debate among a large number of water

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[32] Resource Efficient Europe, COM(2011)21 final.

[33] Eco–Innovation Action Plan COM(2011) 899 final.

[34] European Commission (2012), *World Water Day – EU research on water,* MEMO/12/203, 22/03/2012, Brussels, http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/12/203&format=HTML&aged=0&language=EN&guiLanguage=en

[35] European Commission website at: www.3water.euhttp://ec.europa.eu/environment/greenweek/

[36] European Commission (2012), *3rd European Water Conference*..., op.cit.

stakeholders, Member States, and the European Commission. Environment Commissioner Janez Potočnik said during the Conference: "Progress has been made towards developing a water policy fit to face the challenges ahead. But policy-making can only be as good as the knowledge it is based on. Numerous studies and assessments have helped boost our knowledge and understanding of the current trends, emerging problems and existing gaps in the implementation of our water policy. The 2015 deadline set by the Water Framework Directive to achieve good water status in the EU is just round the corner." Commissioner Potočnik concluded that since: Every drop counts, we should count every drop indeed[37]. Green Week 2012 and particularly the 3rd Water Conference will feed into the Blueprint scheduled for November 2012.

5. Conclusion

The EU's Water Framework Directive makes the maintaining or recreating a good environmental status for river ecosystems mandatory. It does this simultaneously taking into account the need for flood and drought risk management and the use of water for various purposes. However, its complete implementation will have to change the water economies of many EU countries, including the water management of Poland, where these changes are in fact an opportunity to have clean and natural rivers.

There is a long road ahead to meet the ambitious objectives of European water policy, e.g. not all River Basin Management Plans have been submitted, low ambition of these Plans, lack of concreteness and comparability, and dressing up "business as usual" as WFD implementation. The integrated water policy requires cooperation among EU Member States. Moreover, the water aspect must also be reflected in the international development cooperation of the EU. The EC must discuss the possible role of water in other EU policies, including the difficulties of integrating water policy into other policies and ways to reach improved mobilisation of financial resources available in multi–annual budgets for the benefit of water management.

The Blueprint to Safeguard Europe's Water Resources, which has the long–term objective of ensuring the availability of good quality water for sustainable and equitable water use, will form the new EU policy response to the challenges surrounding water as a resource. The European Commission expects the Blueprint to aim to ensure good quality water in sufficient quantities for all

[37] Ibid.

legitimate uses. It will be based on an evaluation of the implementation and achievements of current EU water policy.

Bearing in mind the multitude of problems, needs, and complexity of challenges in the area of the water management in the European Union, it must be stated that the existing water policy framework and the WFD Common Implementation Strategy process should be continued. All relevant actors (agriculture, industry, and households) need to collaborate in achieving water policy objectives, underlining the need for an integrated water management policy that sets medium– and long–term objectives.

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Streszczenie

POLITYKA WODNA UNII EUROPEJSKIEJ: KLUCZOWE PROBLEMY I WYZWANIA

Zasoby wodne należą do najcenniejszych zasobów środowiska naturalnego. Zrównoważona i zintegrowana gospodarka tymi zasobami stanowi podstawę Europejskiej polityki wodnej. Zgodnie z Ramową Dyrektywą Wodną do 2015 roku wszystkie wody w Unii Europejskiej powinny osiągnąć co najmniej dobry stan wód, co jest nadal przedmiotem dyskusji w niektórych państwach członkowskich, w jaki sposób osiągnąć ten cel. Istnieją poważne problemy i opóźnienia w realizacji i wdrażaniu zapisów Dyrektywy w większości krajów członkowskich UE, a w kilku krajach, w tym także i w Polsce, stan gospodarki wodnej został krytycznie oceniony przez Komisję Europejską. Przed Europejską polityką wodną stoi wiele wyzwań, które wymagają rozwiązania na szczeblu globalnym oraz lokalnym. W artykule przedstawiono aktualne kluczowe problemy oraz planowane kierunki rozwoju polityki wodnej UE, poddając je analizie i ocenie. Zwrócono uwagę na najnowsze inicjatywy KE w zakresie polityki wodnej, a w szczególności na plan ochrony zasobów wodnych Europy.

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Social Aspects of Transnational Corporations' Activities in the New EU Member States

Abstract

The aim of this paper is to examine main social aspects related to activities of TNCs in the new EU Member States and to answer the question whether TNCs could help solve some social problems of recipient countries or if their activities are a source of additional imbalances in the social sphere. The UNCTAD, OECD and CEIC statistics data bases are used to analyze and evaluate the scale and consequences of TNCs activities in the new EU member States. The empirical analysis is limited to four countries, i.e. the Czech Republic, Hungary, Poland and Slovakia. The research results show that TNCs can play a positive role in smoothing some social problems in host countries which are unemployment, poverty and social exclusion. TNCs create and maintain a vast portion of jobs in the new EU Member States offering higher compensation for employees than domestic firms. The tendency towards regional concentration of FDI in developed regions has an ambiguous impact on the socio-economic cohesion of the enlarged EU examined at the regional level. TNCs seem to stimulate disparities between regions of the EU and within these regions. TNCs are corporate social responsibility leaders in the new EU Member States.

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1. Introduction

Transnational corporations' activities in the form of foreign direct investment (FDI) cause both economic and social consequences for host countries. While the impact of FDI on economy has already been widely analyzed, social aspects of foreign investors' activities are less recognized, even though they are of paramount importance for the sustainable development of host countries. Transnational corporations (TNCs) have an impact on some characteristics of labor markets in recipient countries, they also influence social inequalities in regions and introduce some corporate social responsibility (CSR) practices often unknown or neglected in recipient countries.

The new EU Member States are in need of capital to modernize their economies and they encourage TNCs to invest in their economies. Social issues related to the activities of TNCs are also important to them because all the new EU Member States experience social problems such as unemployment, poverty in some regions, lack of adequate sources for education and healthcare systems. These countries face serious imbalances of their national budgets and they have little prospects of solving their problems by using public sources. Moreover, they cannot use the social policy of the European Union as a remedy, as it is only additional to the national policies.

The aim of this paper is to examine main social aspects related to activities of TNCs in the new EU Member States and to answer the question whether TNCs could help solve some social problems of recipient countries or if their activities are a source of additional imbalances in the social sphere.

The more detailed tasks of the paper are as follows:

- to present theoretical issues of TNCs activities in the social sphere of recipient countries
- to define main social problems of the new EU Member States
- to show a scale of the Europeanization of the social policy in the EU and its relationship with national social policies of the Member States
- to examine the importance of TNCs for labor markets in the new EU member States
- to evaluate the role of TNCs in creating/or smoothing social inequalities between and within the regions
- to evaluate a scale and forms of TNCs involvement into corporate social responsibility (CSR) practices in the new EU Member States.

The UNCTAD and OECD statistics data bases will be used to analyze and evaluate the scale and consequences of TNCs activities in the new EU member

States. The empirical analysis will be limited to four countries, i.e. the Czech Republic, Hungary, Poland and Slovakia.

2. Theoretical aspects of TNCs activities in the social sphere of recipient countries

TNCs activities in host countries bring both economic and social effects although the latter seem to be less frequently examined. Social issues related to TNCs' involvement in recipient countries are broadly understood (Meyer 2004, Jain, Vachani 2006). They embrace labor standards, functioning of institutions, environmental issues, ethical questions, poverty reduction and social inequalities.

This paper concentrates on some of these issues, i.e.:

- labor market issues
- regional social inequalities
- CSR practices as a part of business ethics.

The relationship between TNCs activities and labor market in host countries is discussed in the context of direct and indirect effects on employment and building skills in host countries (UNCTAD 1994, UNCTAD 1999). These effects depend on TNCs entry modes into host countries (greenfield investment or M&A), on a scale and branch structure of FDI, TNCs strategies and related organizational structures as well as on policies of host countries towards foreign investors. European integration processes modify, to some extent, effects of TNCs activities on labor market. This modification is related to the stages of integration processes and characteristics of TNCs (Witkowska 2001).

Regional development disparities existing in certain host countries are influenced by TNCs' activities. FDI tend to be located in relatively more developed regions of host countries because of their stronger location advantages. This is consistent with J.Dunnig's eclectic paradigm of international production (Dunnig 1977, 1979, 1988). Advanced integration processes enhance spatial concentration of economic activities while free capital and labor movements are established (Molle 1995). This leads to stronger regional social inequalities within host countries because of growing regional disparities in employment, skills and incomes. The EU socio-economic cohesion policy can only partly overcome regional differences in GDP per capita, employment rates and innovation characteristics (Molle 2007).

The literature discusses CSR practices in the context of business ethics, their relations with competitiveness of firms, costs –benefits of stakeholders, motives standing behind and international dimensions of these practices (UNTAD 1999, UNCTAD 2001, Hopkins 2004, Porter, Kramer 2006). The involvement of TNCs in CSR is growing which is confirmed by their participation in global and regional initiatives and actions. The European Union's institutions support a participation of European enterprises in CSR practices (Green Paper 2001, COM 2002, COM 2006). European integration processes, nevertheless, don't seem to influence specificity of CSR practices.

3. Main social problems of the New EU Member States and attempts to solve them

A common feature of the new EU member States are social problems that were caused by systemic transformation processes and adjustments to market economy rules. There are: unemployment and its social consequences, poverty, social exclusion, lack of adequate sources for education and healthcare systems. The EU accepted a new strategy 'Europe 2020' oriented among others on improving social cohesion of the EU. It is a daunting task because of social disparities existing between developed and less developed Member States and their regions. The EU statistical data illustrate the scale of these problems (The European Commission 2010):

- Unemployment - since 2008, has risen dramatically in many Member States, notably in Spain and the Baltic States, where average rates were around 20% by early 2010. In February 2012, the average unemployment rate in EU27 amounted to 10.2%. Three of the new EU Member States (the Czech Republic, Romania and Slovenia) accounted for the lower unemployment rate than the average. In Poland this rate was the same as the average and the other six new Member States experienced the higher unemployment rates, ranging from 11% in Hungary to 14.6% in Latvia (See Graph 1).
- Regional disparities in unemployment have also increased since 2008, although in 2000-2008 a significant decrease in unemployment rates in some regions was observed. Eight of the ten regions in which the unemployment rate decreased the fastest between 2000-2008 were located in the new Member States, i.e. in Poland, Bulgaria and Slovakia.
- Poverty and social exclusion is highly concentrated in less developed Member States and regions where up to a quarter of people are identified as being severely deprived. The share of population with an income level that puts them at risk of poverty (less than 60% of national median disposable income) also differs markedly between countries and even more between regions. For example one in four people is at risk of poverty in Romania but

only one in ten in the Czech Republic. At a regional level the differences are much wider. The list of the ten regions with the highest share of the population with an at-the-risk-of-poverty income includes three regions of the new Member States (two in Romania and one in Bulgaria). At the same time, 2008, there were six regions from the new EU Member States on the list of the ten regions with the lowest share of the population with an at-the-risk-of-poverty income.

- Life expectancy is relatively high in all the EU countries, nevertheless, differences between the regions remain relatively wide. Infant mortality, for example, is substantially higher in Romanian and Bulgarian regions, but also in some of the more remote or economically depressed regions in the EU-15.
- 'Early-school leaving' defined as a percentage of young people aged 18–24 with no education beyond basic schooling occurs in one in four regions. The 'Europe 2020' target in this field is at most 10%. It is worth noting that the ten regions with the lowest share of early school leavers in 2007-2009 were located in Poland (five in ten), the Czech Republic and Slovakia.
- The 'Europe 2020' target of increasing the proportion of those aged 30-34 with a tertiary education degree or equivalent to 40% has been reached in less than one in six regions. The ten regions in which the share of tertiary educated population (age 30-34) increased the fastest between 2000 and 2008 were located in the UK, Poland and Ireland.

As the analyzed countries face serious imbalances of their national budgets the possibility of solving above mentioned social problems by using public sources is strongly limited. The new EU Member States receive financial support from the European Structural Funds and the Cohesion Fund. A vast amount of these financial sources are used for economic and technical modernization, environmental improvement as well as creating human capital.

The new EU Member States cannot, however, treat the EU policies and their instruments as a remedy, because such EU policies as the social and cohesion policies are only additional to the national policies. What's more, the Europeanization of the common social policy is not as advanced as in the case of certain economic policies. The character of EU social policy is "looser" than other EU policies and its range is limited to those fields where member states were willing to surrender certain prerogatives to the European Union level (Jovanović 2005; Witkowska, 2010, pp. 117-138). In the European integration process, there is a strong asymmetry between policies promoting market efficiency and policies promoting social security and equality (Scharpf 2002).

In this context, a question arises if it is justified to expect that TNCs activities in the new EU countries could help solve or at least smooth some social problems in these countries.

4. The importance of TNCs for labor markets in the new EU Member States

An evaluation of an impact of TNCs on labor markets in the new EU Member States encounters a serious setback because of incomplete databases. Nevertheless, accessible OECD data for 2002-2007 show that TNCs activities influenced to a large extent employment and compensation of employees in these countries before the global financial crisis.

The shares of TNCs in the national total number of employees were growing in the Czech Republic and Poland. These shares increased in the Czech Republic from 17.7% in 2002 to 33.1% in 2007 and in Poland from 16.6% to 23.3% respectively (see the Graph 2). It means that almost one third and one quarter of jobs respectively was created or maintained by TNCs in these countries.

Data also show that in all the analyzed countries the shares of TNCs in the national total number of employees in manufacturing were increasing while in services some mixed tendencies were observed. This issue is illustrated by Graph 3 and 4.

It is worth noting that the position of TNCs in some manufacturing branches is prevailing. In all the analyzed countries there are branches in which the shares of TNCs in the overall number of employees amount to over 50%. In some branches these shares are even higher and range from:

- 73% to 84% in a motor industry (Poland and the Czech Republic respectively)
- 71% to 82% in the branch “Radio, TV and communication equipment” (Poland and Slovakia)
- 58% to 75% in the branch “Electrical machinery and electronic equipment” (Poland and Hungary).

The same branches are strongly export-oriented. For example, TNCs account for over 80% of export from these branches in the case of Poland. This implies that TNCs use the new EU Member States as an export platform for goods being motivated by their relatively cheaper labor force. Nevertheless, TNCs create and maintain a vast portion of jobs in the new EU Member States. Existence of some branches is totally dependent on foreign investors. A withdrawal of foreign investment from these countries may cause serious economic and social troubles, especially at regional and local levels where firms with foreign participation are major employers. For example, some disinvestment occurred in some regions of Slovakia in 2009-2010.

Data on compensation of employees show that TNCs’ shares in the national total remuneration payable to employees in the analyzed countries were increasing in 2002-2007. In manufacturing, they ranged from 52% to 59% in the Czech Republic, Hungary and Slovakia in 2006-2007. At the same time TNCs accounted for 37% - 51% of the national total number of employees in manufacturing. The comparison of these data allow to conclude that TNCs pay higher wages and salaries in manufacturing, in cash or in kind as well as the social contributions than domestic firms. In services, the same tendencies were observed although the discussed shares were lower, except the case of the Czech Republic. The graphs 5 and 6 illustrate this observations.

Taking into account the social problems of the new EU Member States referred above, the activities of TNCs could diminish a danger of the growing unemployment and reduce a risk of poverty in some social groups.

5. The role of TNCs in dealing with regional social inequalities

The new EU Member States countries are characterized by both economic and social internal regional inequalities. The experience of these countries shows that TNCs locate their foreign direct investment in the relatively more developed regions of host countries and less in the lagging regions. This was confirmed by the data both before and during the EU membership. For example (CEIC data basis and own calculations):

- in the Czech Republic, 47% -54% of the annual FDI flows were located in the Capital City Praha region in 2000-2009
- in Hungary, about 68% of the annual FDI flows were located in Central Hungary region, 10%-11% in Western Transdanubia and 6%-8% in Central Transdanubia in 2000-2008 respectively
- in Slovakia, about 68% -74% were located in Bratislava region in 2007 - 2009.

In Poland, the capital city region (Mazowieckie) accounted for 56% of inward FDI stock in 2003 and 49% in 2009 (GUS 2004, 2010 and own calculations).

The relatively high degree of regional concentration of FDI in developed regions combined with the higher compensation of employees offered by TNCs have an ambiguous impact on the socio-economic cohesion of the enlarged EU examined at the regional level. FDI seem to stimulate disparities between regions of the EU and within these regions. It consequently makes catching up processes of lagging regions even more difficult.

6. TNCs involvement into corporate social responsibility (CSR) practices in the new EU Member States

TNCs are involved into CSR practices in the new EU Member States more intensively than domestic firms. This is confirmed by the UNDP survey (UNDP 2007), data on the participation of TNCs in the *Global compact* initiative (www.globalcompact.org.pl) and case studies. In the new EU Member States, in their earlier phase of development when the systemic transformation underwent, less attention was paid to social and environmental issues (CSR Europe 2010).Within restructuring processes, post –socialist firms got rid of some social functions, developed in the period of centrally planned economies, treating them as a burden. Although no deeper expectations were raised towards foreign investors with regard to CSR practices, they introduced them into the recipient countries following parent companies' strategies in this field. Nowadays, TNCs are CSR leaders in the new EU Member States and some domestic firms started following them.

TNCs enter into complex social relations in the new EU countries and try to shape them according to their needs (Witkowska 2011, pp.515-528). This allows TNCs to avoid social conflicts that might threaten their interests. Furthermore, TNCs use social relations management as an instrument of increasing company competitiveness. For the new EU Member States, the involvement of TNCs in social issues is beneficial as well. First of all, they diminish a deficit of decent work in these countries. Then, through sponsoring and patronage, they have participation in financing of some events and actions in the cultural or educational sphere that could not be financed from national or local budgets because of a shortage of sources.

7. Conclusions

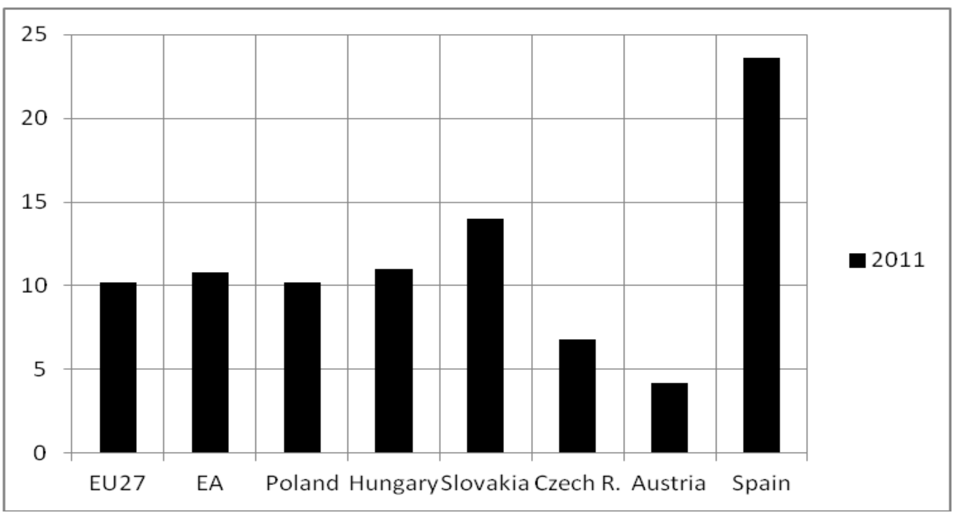
1. Theoretically, TNCs can play a positive role in smoothing some social problems in host countries which are unemployment, poverty and social exclusion. European integration processes can modify only to some extent an impact of TNCs on labor market and regional disparities.
2. TNCs create and maintain a vast portion of jobs in the new EU Member States offering higher compensation for employees than domestic firms. In some branches, TNCs are dominant as employers.
3. The high involvement of TNCs in export from some analyzed countries imply that they are treated as an export platform. Relatively higher

compensation for employees does not constitute a barrier to strongly export-oriented investors.

4. The tendency towards regional concentration of FDI in developed regions has an ambiguous impact on the socio-economic cohesion of the enlarged EU examined at the regional level. TNCs seem to stimulate disparities between regions of the EU and within these regions.
5. TNCs are corporate social responsibility leaders in the new EU Member States. In the social sphere, they are strongly involved in sponsoring and patronage actions. They diminish a deficit of decent work in these countries being involved in different programmes for their workers.

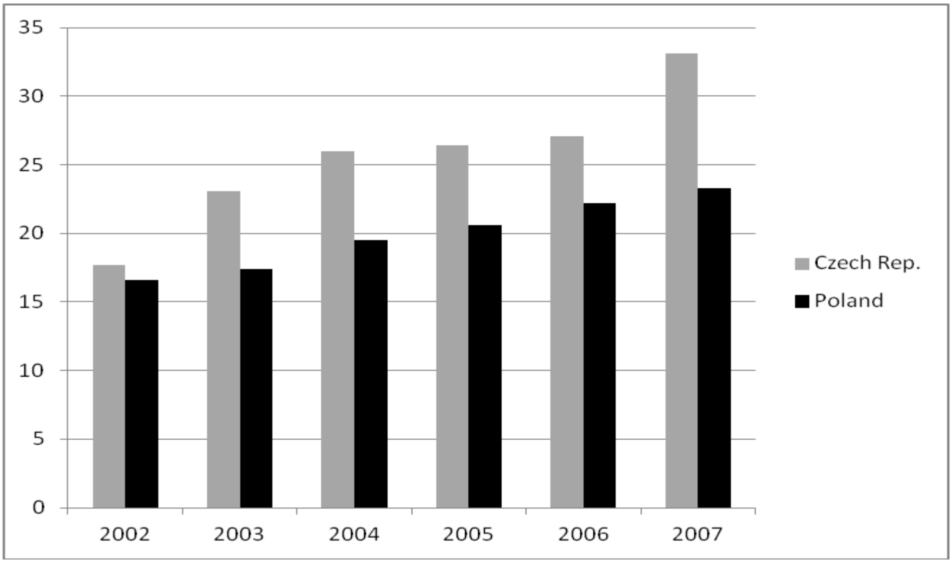
GRAPHS:

Graph 1. Unemployment rates in the EU, EA and the selected EU Member States, 2011, %



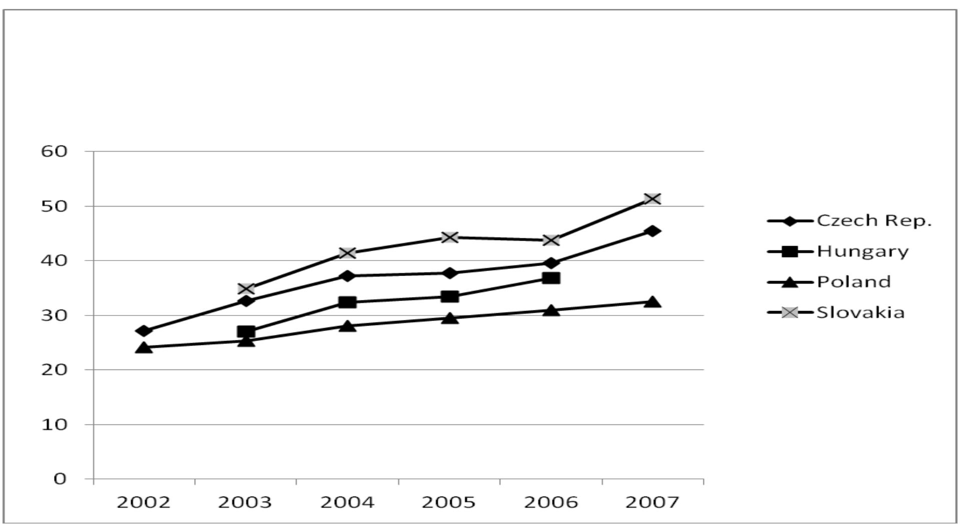
Source: Unemployment rates, seasonally adjusted, February 2012.png - Statistics Explained (2012/4/3)http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Unemployment_rates,_seasonally_adjusted,_February_2012.png&filetimestamp=20120402081419 and own presentation.

Graph 2. The shares of TNCs in the national total number of employees, 2002- 2007, %



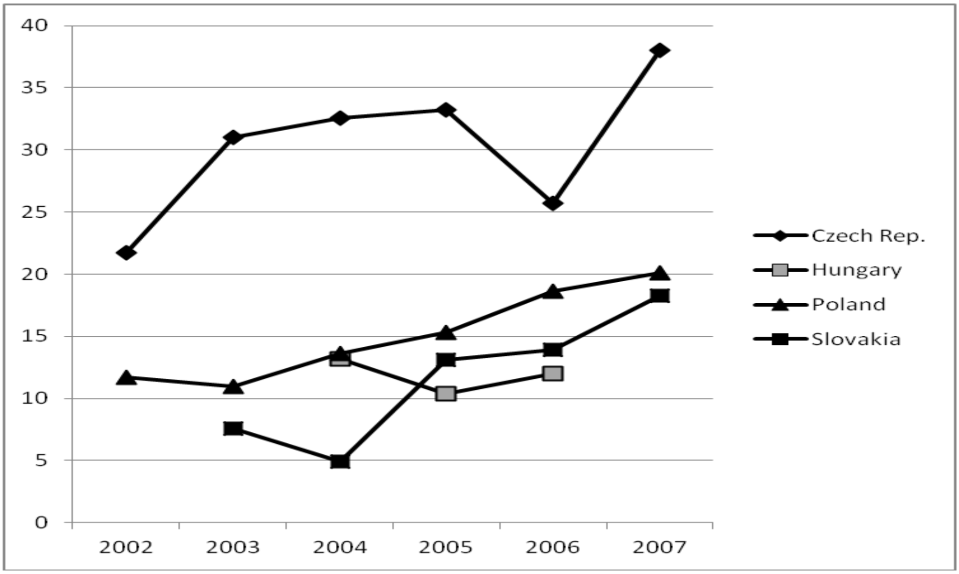
Source: OECD database.

Graph 3. The shares of TNCs in the national total number of employees in manufacturing, 2002-2007, %



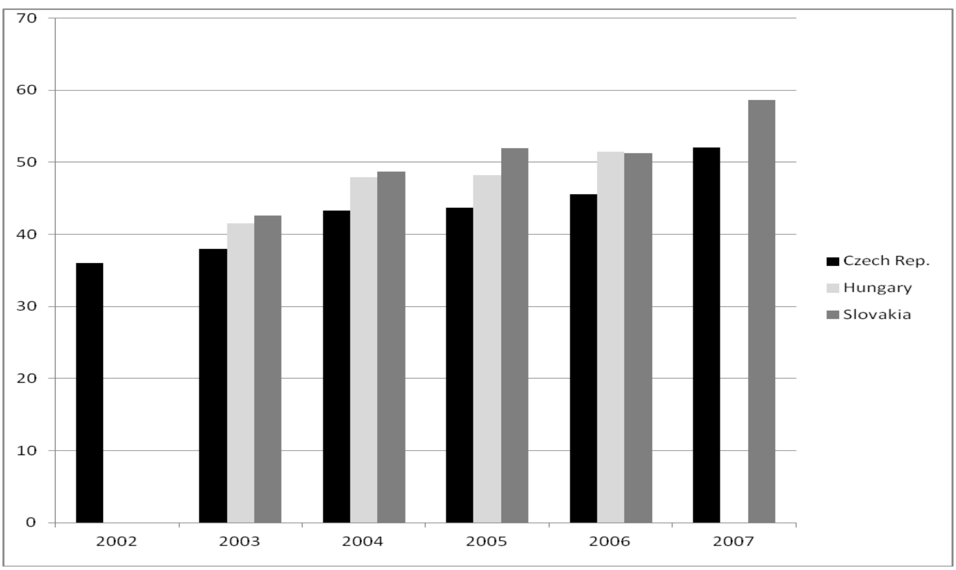
Source: OECD database.

Graph 4. The shares of TNCs in the national total number of employees in finance, insurance, real estate, business activities, 2002- 2007, %



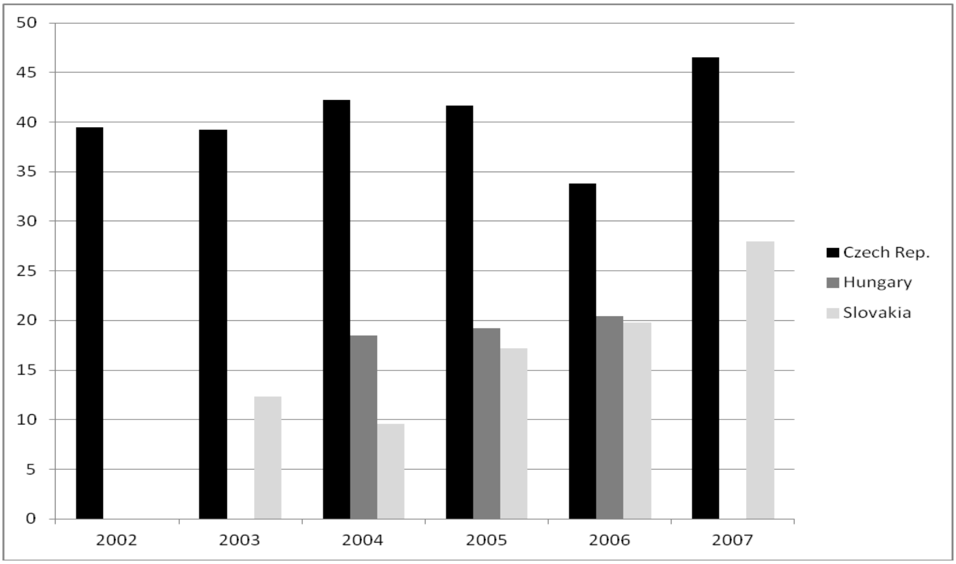
Source: OECD database.

Gaph 5. TNC's shares in the national total compensation of employees in manufacturing, 2002-2007, %



Source: OECD database.

Graph 6. TNC's shares in the national total compensation of employees in finance, insurance, real estate, business activities, 2002-2007, %



Source: OECD database.

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Streszczenie

SPOŁECZNE ASPEKTY DZIAŁALNOŚCI KORPORACJI TRANSNARODOWYCH W NOWYCH KRAJACH CZŁONKOWSKICH UNII EUROPEJSKIEJ

Celem artykułu jest zbadanie głównych społecznych aspektów związanych z działalnością korporacji transnarodowych w nowych krajach członkowskich Unii Europejskiej (UE) oraz próba odpowiedzi na pytanie, czy korporacje transnarodowe mogą pomóc złagodzić społeczne problemy występujące w krajach goszczących, czy też są źródłem dodatkowej nierównowagi w sferze społecznej. Analiza i ocena skali zaangażowania korporacji transnarodowych w nowych krajach członkowskich UE została przeprowadzona z wykorzystaniem bazy danych UNCTAD, OECD i CEIC. Analiza empiryczna obejmuje cztery kraje, tj. Czechy, Węgry, Polskę i Słowację. Wyniki badań wskazują, że korporacje transnarodowe mogą odgrywać pozytywną rolę w łagodzeniu społecznych problemów w krajach goszczących, którymi są bezrobocie, ubóstwo i społeczne wykluczenie. Korporacje transnarodowe tworzą i utrzymują stosunkowo duża liczbę miejsc pracy w nowych krajach członkowskich UE, oferując wyższe wynagrodzenie pracownikom, niż firmy miejscowe. Ich skłonność do koncentracji bezpośrednich inwestycji zagranicznych w rozwiniętych regionach ma jednak niejednoznaczny wpływ na spójność społeczno-ekonomiczną poszerzonej UE, badanej na poziomie regionalnym. Korporacje transnarodowe wydają się stymulować nierówności na poziomie międzyregionalnym i wewnątrz regionów. Jednocześnie korporacje te są liderami społecznej odpowiedzialności w nowych krajach członkowskich UE.

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