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INDUSTRIAL SYMBIOSIS IN EUROPEAN POLICY: OVERVIEW OF RECENT PROGRESS[1]

Abstract. The aim of the paper is to explain the cooperation and processes realized within the industrial networks based on the principles of industrial symbiosis in Denmark, Russia and Slovakia. The identified examples can be characterized as best practices in the field of industrial symbiosis that influences importantly the development of regions, where they are localized. Industrial symbiosis as a voluntary cooperation of enterprises with the aim to optimize production costs and improve the environment could influence positively the development of areas where the companies are operating. The paper includes three examples of 'best practices' from Denmark, Russia and Slovakia. The examples refer the wide range of benefits that this kind of cooperation brings.
Keywords: industrial symbiosis, cooperation, best practices.

1. INTRODUCTION

The development of territories at the beginning of the 21st century is characterized by intensive process of globalization, increasing flexibility and mobility of technique, technologies, capital, people, growing individualism of market segments, growing and intensive competition among territories as well as by increased product substitution and market saturation[2]. Last decade witnessed the emergence of new trends in economic development and industrial symbiosis, the so called eco-industrial parks.

The aim of the paper is to explain the cooperation and processes realized within the industrial networks, based on the principles of industrial symbiosis in

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[1] This paper was prepared as part of the 7th Framework Programme FP7-PEOPLE-2011 IRSES Project No. 295050 FOLPSEC – *Functioning of the local production systems in the conditions of economic crisis (comparative analysis and benchmarking for the EU and beyond)*.

[2] Petríková K., Borseková K., Vaňová A. (2010), *Places marketing as a tool of territorial development and its application in the Liptov region in Slovak Republic*, International Congress „Regulation and Best Practices in Public and Nonprofit Marketing", Bucharest, Romania, International conference proceedings, p. 1–10.

Denmark, Russia and Slovakia. The below presented examples have been selected as best practices in the field of industrial symbiosis, which have exerted significant impact upon the development of regions, in which they operate.

The core of the paper methodology is a case study approach. The case study research method investigates a contemporary phenomenon – exchanges of industrial symbiosis within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used[3]. The paper includes three detailed intensive studies of corporations operating in the field of industrial symbiosis. The case studies focus on the details of exchanges, the attempts of synergies' classification; being major methods of the research in the field, uncover reasons why some mutually beneficial industrial practices are widespread and successful while others are far from being implemented[4]. The paper is an output of the international research project FOLPSEC (orientated to the comparative analysis of LPS systems in Russia, Slovakia, Poland and Bulgaria), which significantly influenced also the choice of presented examples from Slovakia and Russia. The case study from Denmark is a famous example of industrial symbiosis in the world. It seems like a model of industrial symbiosis for learning and improving the functioning of systems in other countries, including Slovakia and Russia.

2. INDUSTRIAL SYMBIOSIS AND ITS OCCURRENCE IN RUSSIA AND SLOVAKIA

Industrial symbiosis is a signature topic in industrial ecology that focuses upon physical exchanges of materials, energy and by-products at the inter-firm level, where the company does not operate as a self-contained unit, but in cooperation with other firms. The theory of industrial symbiosis analyzes mutually beneficial inter-firm exchanges of materials, energy and by-products that take place in one local area, and views formally independent enterprises, usually belonging to separate industries, as interactive parts of one complex organism[5].

Industrial symbiosis is a voluntary cooperation of enterprises with the aim to optimize production costs and improve the environment, the use of by-products and wastes generated by some enterprises as production inputs for others, to share information, services, utilities, energy, and other resources. It has been defined as a process engaging "traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water,

[3] Yin R.K. (1984), *Case study research: Design and methods*, Sage, Newbury Park, CA.

[4] Gibbs D., Deutz P. (2007), *Reflections on implementing industrial ecology through eco-industrial park development*, "Journal of Cleaner Production", no. 15(17), p. 1683–1695.

[5] Wolf A., Petersson K. (2007), *Industrial symbiosis in the Swedish forest industry*, "Progress in Industrial Ecology", vol. 4, no. 5, p. 348–362.

and by-products. The keys to industrial symbiosis are collaboration and synergistic possibilities offered by geographic proximity"[6]. The main idea of industrial symbiosis as a part of industrial ecology is to reduce virgin material and energy inputs by utilizing waste, by-products, and waste energy through the exchanges among relevant stakeholders[7].

Industrial symbiosis research demonstrates how inter-industry cooperation may create comparative advantages and produce synergies for businesses that act in geographic proximity[8]. Chertow[9] distinguished between two models of industrial symbiosis development – a planned model and a self-organising model (spontaneous) of industrial symbiosis. Regrettably, spontaneous development of industrial symbiotic networks happens rather rarely, and its emergence requires a long period of time. It is dependent on the way how the social, economic, technical and political conditions embedded in the geographical settings support or influence the industrial by-product exchanges. If they are more proactive, there is more chance of development (Mirata, 2005[10]; van Beers et al. 2007[11]; Baas 2008[12]).

Nowadays we know several forms of planned industrial ecosystems, where companies are interconnected via integrated use of energy, waste material or by-products. Eco-industrial parks are known to be the most widespread form of artificial modeling of symbiotic systems, whose functioning implies the existence of close inter-firm connections that resemble the ties typical for natural ecosystems. As a rule, the development of an eco-industrial park is limited by the borders of one industrial agglomeration. An alternative approach to the creation of planned inter-firm network assumes the teaming up of businesses located in different regions but looking for the establishment of symbiotic ties for a variety of reasons, beginning with the natural desire to exploit win-win situations among firms. However, planned eco-industrial initiatives have resulted in many failures. A coordinative function was found to be undoubtedly helpful only to accelerate

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[6] Chertow M.R. (2000), *Industrial symbiosis: Literature and taxonomy*, "Annual Review of Energy and Environment", vol. 25, p. 313–337.

[7] Korhonen J., Snäkin J.P. (2003), *Industrial ecosystem evolution of North Karelia heating energy system*, "Regional Environmental Change", no. 3(4), p. 1–12.

[8] Berkel van R. (2006), *Regional resource synergies for sustainable development in heavy industrial areas. An overview of Opportunities and Experiences*, Curtin University of Technology, Perth, WA, Australia.

[9] Chertow M.R. (2007), *Uncovering "industrial symbiosis"*, "Journal of Industrial Ecology", no. 11(1), p. 11–30.

[10] Miarata M. (2005), *Industrial Symbiosis. A Tool for More Sustainable Regions?*, IIIEEE, Lund University, Sweden.

[11] Baas L. (2008), *Industrial Symbiosis in the Rotterdam Harbour and industrial complex: reflections on the interconnection of the techno-sphere with the social system*, "Business Strategy and the Environment", no. 17, p. 330–340.

[12] van Beers D. et al. (2007), *Industrial symbiosis in the Australian minerals industry*, "Journal of Industrial Ecology", no. 11(1), p. 55–72.

the number and complexity of new exchanges working from an established base[13]. Given both economic and environmental gains of industrial symbiosis, the question is whether government interventions might be effective to design and build a viable eco-industrial system.

Still, at the firm level, the motivation behind most of the exchanges is to reduce costs by seeking income-producing applications for unwanted by-products and waste, and the emergence of the multilateral resource sharing in the form of industrial symbiosis could be promoted by local environmental regulations.

In Russia, however, regulatory conditions do not encourage voluntary exchanges among industrial neighbors. The only motivation there is to achieve private benefit or to reduce private costs.

The main reason why Russian business today pays more attention to the activities mitigating the adverse impact on the environment appears to be neither the ecological legislation, nor the control by the government regulatory bodies. Paradoxically, competitive market incentives make the companies reduce costs and introduce modern technologies, which, being efficient commercially, tend coincidentally to be also less energy-consuming and more environment-friendly.

The government does not motivate businesses enough to increase investments in environmental protection projects and to reduce pollution. Russian environmental regulations suffer from serious deficiencies. The main problem is fiscal orientation of the existing system of pollution fines. The formerly applied practice, when fines could be conditionally reduced in return for investments in pollution reduction, has become very uncommon, especially with respect to small and medium sized enterprises. In addition, regional authorities take more interest in collecting pollution fines as extra budget revenues rather than in reducing the adverse environmental impact. Having a legal status of a compensatory payment, pollution fines nevertheless are commonly used by governments at any level of the federal hierarchy to finance their current needs, not just for environmental protection.

The acting system of ecological standards is also not beyond reproach. Russian law assumes environmental quality standards that are higher than those in the U.S. or Europe. The norms are the same for all parts of the country, disregarding differences in background pollution levels. However, there is a possibility for local authorities to set individual standards of acceptable adverse impact on the environment and the deadlines for their attainment.

Finally, experts estimate that about 80 per cent of Russia's environmental legislative acts have been never used across its territory[14].

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[13] Jacobsen N.B., Anderberg S. (2005), *Understanding the evolution of industrial symbiotic networks – The case of Kalundborg*, [in:] M.J.J.C.J.M. van den Bergh (ed.), *Economics of Industrial Ecology: Materials, Structural Change, and Spatial Scales*, MIT Press, Cambridge, MA.

[14] Round Table "Business and Environment", http://top.rbc.ru/pressconf/04/10/2012/671862.shtml.

Thus, environmental policy interventions could be viable means of motivating wastes and by-products flows among firms, but not in the case of Russia. Currently, as in the very beginning of the iconic Kalundborg industrial symbiosis story, the only incentive for entrepreneurs might be cost savings from reduced waste management and improved production efficiency.

In the Slovak Republic, the term industrial symbiosis is not so well known. There are a few examples of industrial symbiosis networks (e.g. Detva described at p. 6), but they were not established primarily as eco-parks or other forms of industrial symbiosis, they have developed over decades and they are rooted in the historical economic development of Slovakia.

Nowadays, the first conceptual incentives to research the conditions of industrial symbiosis in the Slovak private sector have appeared under the project REPROWIS. In 2010–2011 the project enabled a research conducted among 500 small and medium enterprises. The aim of the project was to identify the possibilities how to connect businesses when it comes to inputs, outputs and free capacities. According to the results, only seven out of 500 businesses implemented the environmental management system – ISO 14001. The most common forms of environmental pollution are waste, air and water pollutions. Lack of interest or lack of information about techniques for reducing negative environmental impacts have been identified as the most common barriers to the implementation of eco-innovation processes in companies. Companies do not have any priorities relating to environmental protection, their preferences focus around financial aims, namely profit. Environmentally friendly activities are implemented only if they do not involve cost[15]. These findings indicate problematic issues of industrial symbiosis implementation in Slovak Republic.

3. INDUSTRIAL SYMBIOSIS ON THE EXAMPLES OF KALUNDBORG (DENMARK), NOVOSIBIRSK (RUSSIA), DETVA (SLOVAKIA)

Kalundborg (Denmark)

The Kalundborg example shows that a single exchange between nearby firms could be the first step towards the development of industrial symbiosis. As identified in the industrial symbiosis literature, "successful initiation of trading within co-located firms appears to bring a shift in thinking creating a willingness to consider further trading"[16].

[15] Study of Application of Industrial Symbiosis (Is) As a Tool to Reduce Production Waste. Project REPROWIS. Accessed: http://reprowis.eu//img/files/IS-Study.pdf; 2.09.2013.

[16] Chertowand M.R., Lombardi D.R. (2005), *Quantifying Economic and Environmental Benefits of Co-Located Firms*, "Environmental Science & Technology", vol. 39, no. 17, p. 6535–6541.

Symbiotic networks sometimes arise spontaneously, as it happened in Kalundborg, Denmark[17]. Today, one can find there a world-famous model of industrial symbiosis in action. The core of partners includes:

- Asnæs Power Station, Denmark's largest power station, coal-fired, 1,500 megawatts capacity,
- Gyproc, a plasterboard factory, making 14 million square meters of gypsum wallboard annually,
- Statoil Refinery, Denmark's largest, with a capacity of 3.2 million tons/yr (increasing to 4.8 million tons/yr),
- Novo Nordisk, an international biotechnological company, the plant at Kalundborg produces pharmaceuticals (including 40% of the world's supply of insulin) and industrial enzymes, and
- The City of Kalundborg supplies district heating to the 20,000 residents, as well as water to the homes and industries.

The symbiosis started in early 1970s, when Gyproc established plaster-board manufacturing plant in Kalundborg and constructed a pipeline to take advantage of the excess refinery gas available from Statoil refinery. Since then, the network has been developed spontaneously through a series of contracts, negotiated on a bilateral basis. In 1979, Asnæs started to supply fly ash to cement manufacturers; two years later, in 1981, the Kalundborg municipality completed a heating distribution network within the city that utilized steam from the power plant. Next year, Novo Nordisk and Statoil began to purchase process steam from the power plant. In 1989, a fish farm started to use hot sea water from Asnæs. Three years later, the power plant began consuming surplus flare gas as a supplementary fuel to substitute some amount of coal (this activity came into play in response to a regulatory changes and impetus for Statoil to pursue gas desulfurization, after that it became clean enough to meet power plant technological requirements). Fish wastes and biological sludge from Novo Nordisk's processes (since 1976) are supplied to neighboring farms as fertilizer. Novo Nordisk also supplies farms with surplus yeast from insulin production for pig food. The Statoil refinery delivers pure liquid sulphur from its desulphurization operations to Kemira, a sulphuric acid producer. Moreover, these exchanges are only part of the energy and material flow of the Kalundborg eco-park. As a result of over 30 years of development, bilateral links evolved to a highly integrated web of recycling and sharing of a variety of materials, energy and wastes. The close cooperation has allowed a dramatic increase in the sustainability of products and development.

The structure of all activities involved in the industrial symbiosis in Kalundborg is presented in the figure 1.

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[17] See: www.symbiosis.dk.

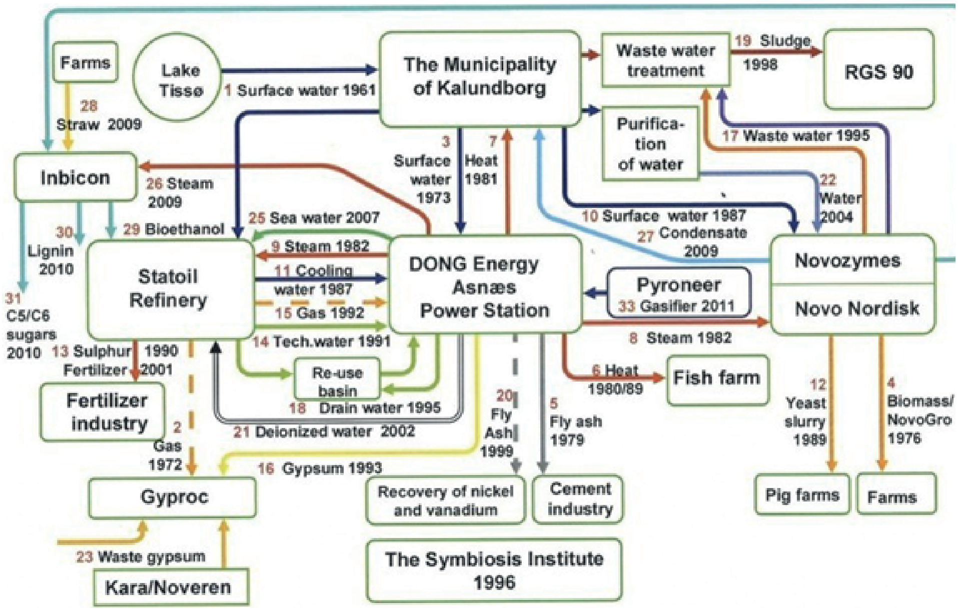

Figure 1. The system of industrial symbiosis in Kalundborg

Source: http://www.symbiosis.dk/en/system.

By-product exchanges in the Kalundborg Symbiosis are subject to continuous changes caused by the impact of technological and legislative developments on the market of wastes and by-products.

For instance, until recently, Statoil refinery supplied liquid sulphur, a by-product of crude desulphurization, to Kemira, a producer of sulphuric acid. However, industrial symbiosis requires by-product supplies to be based upon conventional market relationships and mutual economic benefits. Hence, Statoil stopped the sulphur shipments when its partner moved production from Denmark to Finland and the cooperation lost its economic appeal because of increased transportation costs.

Searching for new opportunities to sell its by-product, Statoil acquired a patented technology to manufacture ammonium sulphate aiming to sell it to a fertilizer producer Dan Gødning, whose production capacities are located out the limits of the industrial park. Also, the company had to stop its butane shipments to a Gypros plant when that facility switched to less expensive natural gas[18]. Another example of innovation processes' impact on industrial symbiosis development is the recent

[18] Herczeg G., Akkerman R., Hauschild M.Z. (2013), *Supply chain coordination in industrial symbiosis*, Proceedings of the 20th International EurOMA Conference, June 7–12, 2013, Dublin, Ireland, paper SCM-19. URL: http://www.symbiosis.dk/sites/default/files/Herczeg%20et%20al%20%202013_0.pdf.

construction of a weed-growing farm on a water-purifying station, in order to implement a novel technology of high-quality biomass production.

The above-mentioned agreements hardly provide the full list of the energy and material flows in Kalundborg where more than forty years of cooperation resulted in the formation of a complex mutli-dimensional network of two-sided ties allowing for lower costs and higher ecological efficiency of production.

A specific feature of the Kalundborg industrial symbiosis is the social and environmental awareness of the member companies demonstrated by their continuous pursuit to implement cleaner technologies on the whole territory of the industrial park, by making the region attractive for new investors, by promoting more employment and by the development of local infrastructure. Within the administrative borders of the community, there is also a Symbiosis Center that fulfils the purpose of informing member companies about available opportunities, warning of existing problems, and discussing strategies for further development.

The Kalundborg industrial ecosystem was the first one discovered and studied; however, since then other self-organized industrial symbiosis networks have been identified in the economic literature. In 1996, a recycling network of more than 50 facilities in the Austrian province of Styria was founded and is still in operation[19]. Among the frequently cited instances of industrial symbiosis there are also the petrochemical complex at Sarnia (Ontario, Canada)[20] and Guayama (Puerto Rico)[21].

Novosibirisk (Russia)

Presumably one of the first cases of symbiosis development was the one involving one of Russia's largest producers of kernel and oil from Siberian cedar pine nuts (which employs ca. 60 people in Novosibirsk). This one began in 2006, when a pine nuts firm decided to utilize its own by-product, pine nutshells, as a fuel for its boiler installation. Until 2006, nutshells were used to fill in highway pavement cavities and nearby ravines (free of charge). One more remark about environmental regulations in Russia: if pine nuts producer had dumped the nutshells at the community open landfill, it would have been charged for waste disposal[22].

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[19] Schwarz E.J., Steininger K.W. (1997), *Implementing nature's lesson: The industrial recycling network enhancing regional development*, "Journal of Cleaner Production", no. 5(1–2), p. 47–56.

[20] Desrochers P. (2002), *Cities and Industrial symbiosis: Some historical perspectives and policy implications*, "Journal of Industrial Ecology", no. 5, p. 29–44.

[21] Chertow M.R., Lombardi D.R. (2005), *op. cit*, vol. 39, no. 17, p. 6535–6541.

[22] Source: series of interviews with the production manager. Interviews were conducted by the authors as a part of research developed under the Project No. FPT.PEOPLE-2O11-IRSES 295050

Having set the target for reducing waste volumes and resource consumption, in 2006 the enterprise built its own boiler house, equipped with a 200-kilowatt boiler adapted for the use of any non-liquid fuel that could be dispensed – sawdust, sunflower pods, nutshells or anything alike. The heat has been used mainly for technological needs (nut desiccation) and for work rooms heating. Besides, extra tubes were laid, and a boiler manifold was constructed that allows for the regulation of the load distribution between the centralized city heating system and its own heating facility, depending on the weather.

This year, the boiler did not burn all the nutshells and some additional beneficial reuses of the by-product were contracted with an enterprise operating in mulching and landscape design field and with another one from the cosmetic industry. By 2011, a larger network of exchange had evolved. It had been motivated purely by would-be revenues from nutshells sales and savings in disposal costs.

In 2011, 1,850 tons of pine nuts were procured, which resulted in 1,150 tons of nutshells (the actual amounts of nutshells varied and will continue to do so due to changes in a year's pine cones yield). This year, the pine nuts firm supplied 240 tons of the by-product to the enterprise using pine nutshells as a replenisher to produce a drilling agent for the oil industry (also known as tuf – plug). Additionally, about 20 tons were purchased by different partners for mulching and landscape design purposes.

To transform waste into valuable input for the cosmetic firm, which contracted 2–2.5 tons annually of a specific fraction of the by-product, pine nutshells were dried, milled and sifted out before delivery.

The following year, 2012, the pine nuts firm procured 5,580 tons of pine nuts, 4,000 tons were used in production and the rest were dried and stored for the next year. As a result they obtained 2,680 tons of pine nutshells, but nothing was sold to the partners, as this time additional newly constructed boilers consumed all the nutshells produced and the enterprise was not motivated anymore to team up with outside users. Utilization of the by-product as a fuel helps to make the enterprise more and more energy-efficient and to improve its environmental performance.

Detva (Slovakia)

The industrial symbiosis is a possible way of territorial development also for the post transitive economies in Central and Eastern Europe. In Slovakia, agricultural production has got a long tradition. Until 1989, agricultural production was delivered mainly by agriculture cooperatives dealing with stock breeding and

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Functioning of the local production systems in the Conditions of Economic Crisis (Comparative Analysis and Benchmarking for the EU and Beyond) (FOLSPEC).

cultivation of crops. They were also important employers in the countryside. Long cycle of agricultural production is caused by very favorable nature and climate conditions. The southern part of Slovakia enjoys very fertile soil, while its central part is covered with many hectares of grassland, suitable for stockbreeding especially cows and sheep.

After the year 1990, the situation of agricultural cooperative movement in Slovakia changed as a result of transformations. A lot of agricultural cooperatives have become private entities; soil was rent or sold. In 1998 in Vígľaš Agrosev, Ltd. company was established based on the principles of agricultural cooperative. The company started with the production of agricultural products and cow breeding for milk production in the dairy, in Hriňová. In the years to come, its activities expanded and new agricultural cooperatives were purchased in Detva and Lovinobaňa, then in Dúbravy – part Želobudza, in Poniky and Zvolenská Slatina. Nowadays, the core of the company activities is crop and livestock production. Its production is highly appreciated also by lovak competitors[23].

The company invests to improve agricultural premises and searched for new possibilities to reuse and utilize the outputs of animal production. It resulted in building a 1 MW biogas plant in Detva in 2009, which in 2012 expanded to 2 MW power and in the same year also a second 1 MW biogas plant was put into operation in Želobuza.

In the field of crop production, the company farms 5,200 ha of land, including 2,500 ha of soil. The fields are situated within the 35 km from Detva (the main site of the company). Main agricultural crops include winter rape and wheat. The average wheat yield is 4.5–5.5 t/ha and rape yield 2.5–3.3 t/ha. Spring crops include barley, oats, mixes, sorghum and maize. The products are also important as input for animal production and bio-gas station, especially maize used for ensiling and grain.

Animal production is focused on cattle and sheep breeding and takes place in animal farms in Detva, Želobuza, Lovinobaňa, Vígľaš – salaš Palakovo, Studienec. The localization of farms saves the cost of transport of feed commodities. Cattle breeding is divided into cattle for milk and meat production.

The tradition of sheep farming in the locality defines the character of the country covered by many acres of pastures. The biggest farm is situated in Vigľaš – salaš Palakovo, smaller ones in Detva – Stavanisko and Detva Studienec.

To utilize the outputs of plant and animal production, the idea of gas plant was put into practice. The major part of fuels comes from the production of manure and slurry. Other sources of fuel are maize silage and sorghum. The first gas plant was built in 2009 with the power 1 MW/H. It was rebuilt and

[23] See: (http://agrosev.sk).

expanded in 2012; the second one was built in Želobuza. The total power of gas plants is 3 MW per hour. Gas plants produce waste heat used for heating Detva location and fugue used as a quality fertilizer to increase crop production.

The next group of company activities covers processing of agricultural and wood biomass by crushing wood chips. The company has got technology and equipment able to crush small branches and cuttings but also trees average diameter of 70 cm. Its daily output varies from 30 to 200 tons of sliced wood chips. The installation is not used only for commercial purposes, but also to improve soil exploitation, cleaning the water canals and to decrease the risk of flooding.

Both projects – the plant and the production of wood chips were co-financed by the European Union. Applications for the grant had to be drafted in advance and demonstrate that the project and its results will meet the objectives and comply with the laws of the European Union and the Slovak Republic, especially in the area of environment. The main legal acts and regulations include *at the EU level:*

– Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control,

– Council Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management,

– Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants,

at the national and regional level:

- acts, decrees and communications in the fields of environment, air quality protection, state environmental policy,
- National environmental action plan,
- National strategy of sustainable development,
- Strategy, principles and priorities of state environmental policy,
- Plan of economic and social development in the region of Banská Bystrica,
- Plan of economic and social development in Detva,
- Development concept of Detva in the field of heat energy and etc.

The sister company of Agrosev – Koliba, ltd. – the dairy plant processes milk produced from cattle breeding. During last decade, the plant was modernized; the technology was improved, which was confirmed by quality certificates STN EN ISO 9001:2008, STN EN ISO 22000:2005; HACCP. The offer of products is diverse. It consist of natural cheese, processed cheese, soft cheese, goat cheese, curd, butters, spreads, yogurts, milk, cream, sour milk drinks etc.

Table 1

Features of examples of industrial symbiosis

Examples of industrial symbiosis			
1	**2**	**3**	**4**
Place	**Kalendbourg**	**Novosibirsk**	**Detva**
State	Denmark	Russia	Slovakia
Year of establishment	1970	2006	1989
Way of establishment	spontaneously	dominant partner developing activities	dominant partner developing activities
Partners	nine public and private enterprises:	private enterprises:	private enterprises:
	Novo Nordisk	producer of kernel and oil from Siberian cedar pine nuts	Agrosev (farms, biogas station, concrete plant)
	Novozymes	company for mulching and landscape design	Koliba (dairy)
	Gyproc	company for cosmetics production	Bytes (manufacture, distribution and sale of heat and hot water)
	Kalendburg Municipality		
	Dong Energy		
	RGS 90		
	Statoil		
	Kara/Novoren		
	Kalundborg Forsyning A/S		
Area of industry	pharmaceutics	food production	agriculture
	chemistry	energy	food production
	energy	pharmaceutical products	bioenergetics
	petrochemical products	oil industry	
	fishing		
Examples of reusing the waste or by-products	refinery gas used by a plaster-board manufacturing plant	pine nutshells as a fuel for boiler installation	biomass production
	using fly ash to cement manufacturers	by-products used in the cosmetic industry	heat distribution from the biogas station
	heat distribution	producing a drilling agent for the oil industry	fertilizers
	hot sea water used at the fish farm	mulching and landscape design	

1	2	3	4
Examples of reusing the waste or by-products	using surplus flare gas as supplementary fuel		
	fish waste and biological sludge used as fertilizer		
	surplus from insulin production used for pig food		

Source: own studies.

4. CONCLUSIONS

Industrial symbiosis and its new forms have great potential in environmentally friendly development of territories. Rational approach of businesses to reuse the by-products and utilize them in cooperation within the net of collaborating companies is the precondition for practical implementation of industrial symbiosis. The process has to be supported by national and international legislation in the field of environmental protection and it should motivate businesses to behave more environmentally friendly.

In the paper we describe three examples of "best practices" of industrial symbiosis. The first one is the example of Kalundborg where the system of industrial symbiosis is the most developed and well known. The examples of Novosibirsk and Detva uncover the potential of the areas to introduce industrial symbiosis also in central Europe and Siberian part of Russia.

REFERENCES

Baas L. (2008), *Industrial Symbiosis in the Rotterdam Harbour and industrial complex: reflections on the interconnection of the techno-sphere with the social system*, "Business Strategy and the Environment", no. 17, p. 330–340.

van Beers D. et al. (2007), *Industrial symbiosis in the Australian minerals industry*, "Journal of Industrial Ecology", no. 11(1), p. 55–72.

Berkel van R. (2006), *Regional resource synergies for sustainable development in heavy industrial areas. An overview of Opportunities and Experiences*, Curtin University of Technology, Perth, WA, Australia.

Chertow M.R. (2000), *Industrial symbiosis: Literature and taxonomy*, "Annual Review of Energy and Environment", vol. 25, p. 313–337.

Chertow M.R., Lombardi D.R. (2005), *Quantifying Economic and Environmental Benefits of Co-Located Firms*, "Environmental Science & Technology", vol. 39, no. 17, p. 6535–6541.

Chertow M.R. (2007), *Uncovering "industrial symbiosis"*, "Journal of Industrial Ecology", no. 11(1), p. 11–30.

Desrochers P. (2002), *Cities and Industrial symbiosis: Some historical perspectives and policy implications*, "Journal of Industrial Ecology", no. 5, p. 29–44.

Gibbs D., Deutz P. (2007), *Reflections on implementing industrial ecology through eco-industrial park development*, "Journal of Cleaner Production", no. 15(17), p. 1683–1695.

Herczeg G., Akkerman R., Hauschild M.Z. (2013), *Supply chain coordination in industrial symbiosis*, Proceedings of the 20th International EurOMA Conference, June 7–12, 2013, Dublin, Ireland, paper SCM-19. URL: http://www.symbiosis.dk/sites/default/files/Herczeg%20et%20al%20%202013_0.pdf.

Jacobsen N.B., Anderberg S. (2005), *Understanding the evolution of industrial symbiotic networks – The case of Kalundborg*, [in:] M.J.J.C.J.M. van den Bergh (ed.), *Economics of Industrial Ecology: Materials, Structural Change, and Spatial Scales*, MIT Press, Cambridge, MA.

Korhonen J., Snäkin J.P. (2003), *Industrial ecosystem evolution of North Karelia heating energy system*, "Regional Environmental Change", no. 3(4), p. 1–12.

Miarata M. (2005), *Industrial Symbiosis. A Tool for More Sustainable Regions?*, IIIEEE, Lund University, Sweden.

Petríková K., Borseková K., Vaňová A. (2010), *Places marketing as a tool of territorial development and its application in the Liptov region in Slovak Republic*, International Congress "Regulation and Best Practices in Public and Nonprofit Marketing", Bucharest, Romania, International conference proceedings, p. 1–10.

Round Table "Business and Environment", http://top.rbc.ru/pressconf/04/10/2012/671862.shtml.

Schwarz E.J., Steiniger K.W. (1997), *Implementing nature's lesson: the industrial recycling network enhancing regional development*, "Journal of Cleaner Production", vol. 5, p. 47–56.

Study of Application of Industrial Symbiosis (Is) As a Tool to Reduce Production Waste, Project REPROWIS. Accessed: http://reprowis.eu//img/files/IS-Study.pdf, 2.09.2013.

Wolf A., Petersson K. (2007), *Industrial symbiosis in the Swedish forest industry*, "Progress in Industrial Ecology", vol. 4, no. 5, p. 348–362.

Yin R.K. (1984), *Case study research: Design and methods*, Sage, Newbury Park, CA.

www.agrosev.sk.

www.symbiosis.dk.