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Ministry of the Environment
of the Czech Republic

Environmental Technologies and Eco-innovation

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Editor: Helena Kollarová (CENIA)

Authors: Vladimír Adamec (CDV Brno), Stanislav Bartusek (VŠB-TU Ostrava), Miloslava Behnerová (CENIA), Hynek Beneš (MŽP), Vladislav Bízek (Technologické centrum AV ČR), Vladimír Čablík (VŠB-TU Ostrava), Ivo Dostál (CDV Brno), Jiří Dufek (CDV Brno), Peter Fečko (VŠB-TU Ostrava), Miroslav Hájek (MŽP), Miluše Hlavatá (VŠB-TU Ostrava), Josef Horák (VŠCHT), Rudolf Cholava (CDV Brno), Antonín Jelínek (VÚZT), Zuzana Kábrtová (CENIA), Jan Kolář (CENIA), Alena Krejčová (SCHP), Roman Ličbinský (CDV Brno), Miloš Maier (ORGREZ, a.s.), Rostislav Malý (ORGREZ, a.s.), Alena Marková (MŽP), Klára Najmanová (MŽP), Ladislav Novák (SCHP), Olga Novotná (CENIA), Jan Prášek (CENIA), Světlana Svitáková (MŽP), Martin Šilhan (SCHP), Ladislav Špaček (SCHP), Ivana Špelinová (CENIA), Libor Špička (CDV Brno), Václav Šťastný (VÚV), Markéta Valtová (CENIA), Zdenka Vdovcová (CENIA), Miroslav Vlasák (CENIA), Lucie Vravníková (CENIA), Filip Wanner (VÚV), Petra Zabloudilová (VÚZT), František Zapletal (ORGREZ, a.s.), Jan Zeman (CENIA), Eva Zichová (CENIA)

Translation into English: Lucie Kráglová

Opponent: Vladimír Študent (CEMC)

Contributors: Leona Matoušková (CENIA), Jan Mertl (CENIA), Lenka Pátková (CENIA), Jana Petruchová (CENIA), Pavlína Slavíková (CENIA), Martina Svobodová (CENIA), Lenka Volaufová (CENIA)

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Content

Foreword

Environmental protection is one of the most influential factors that shape business conditions, especially for manufacturing. Every production process involves a certain degree of direct and indirect pollution. This has to be removed either by cleaning technologies or by decreasing the environmental impact of the production process. For the very first time, this publication divides these technologies into first and second generation technologies, i.e. those of cleaning and low-emission.

Recent technological developments have shown that in addition to the necessity of fast assertion on the market as an innovating driving force, another important impulse is environmental legislation, or rather the intention to significantly economically affect current production systems though legislation. The objective of the “20:20 by 2020” European climate-energy package is clearly to be a marketing slogan, not the realization of potential energy and carbon savings based on calculations. Nevertheless, this slogan has helped. In less than two years of discussions over climate change and European commitments in this area, many innovative changes have been made, e.g. in the development of low-emission and energy efficient car engines.

Second generation technologies, with their greater energy savings potential and environmental friendliness than technologies within the same product group, have shown that true economically efficient environmental protection occurs only in a commercially conforming environment. Even though some “ecologising” measures are financially demanding, market conditions and competition do not allow manufactures to add these costs to the price of a product. Instead, they must look for alternatives that will meet environmental criteria while ensuring their product’s competitiveness. This is the essence of the “win-win” effect, an environmentally and economically friendly innovation.

This is also a reason why supporting environmentally friendly technologies and understanding their importance in overcoming Europe’s economic recession, which we constantly hear about from powerful voices, does not have to be an empty phrase, a useless green slogan without substance, but rather a path to a more effective and sustainable economy.

To make this support happen is a hard nut to crack. There are several tools that can be used to accomplish this and one convenient option is public sector demand since it is one of the largest customers. On the other hand, it is true that excessively regulating production and support for selected entities is a path best avoided over the mid-term horizon.

In other words, create a framework and let the market work.

From the long-term perspective, it is the only way to maintain sustainable development both within and outside the Czech Republic.

Rut Bízková
Deputy Minister of the Environment

Introduction

Using environmental technologies and supporting eco-innovation have been the centre of attention all over the world. The European Commission considers this sphere crucial for the future economic development of the EU. Therefore, a number of programmes have been implemented both at the European and national levels to support environmental technologies that are focused on the widest range of eco-innovation and environmental technologies so that they can be applied in all industrial branches. The main objective of this publication is to introduce the issue and map the current state of environmentally friendly technologies in the Czech Republic.

The publication's orientation is based on the definitions of the terms "eco-innovation" and "environmental technology". These set the general framework for the entire publication. The division of the publication based on industrial sections is supposed to primarily cover branches where a high potential of eco-innovation and the use of environmentally friendly technologies can be expected in the Czech Republic. Selected branches are described rather generally, while in other cases information is focused on specific technologies, providing a clear picture of the application of specific environmental technologies in practice. This publication primarily provides initial information in order to arouse interest in environmentally friendly technologies in the general and the professional public without striving to exhaustively describe all the specifics of environmental technologies and eco-innovations in a given sector.

Releasing this publication during the Czech Republic's EU presidency can be used as a method of presenting eco-innovation and environmental technologies not only through research and development and actual production processes, but also by providing examples of the practical application of certain technologies.

Environmental Protection Policy

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1 | Environmental Protection Policy

Environmental protection policy has been one of the priorities of the world's most developed countries and all important international bodies (UNO, OECD, EU) **for several decades. The most burning global problem is currently the risk of climate change. There are more problems, though – the availability of water, air pollution, increasing waste production, reduced biological diversity, deforestation, desertification and others.**

Environmental protection is generally perceived as a part of a wider concept of sustainable development that tries to find equilibrium between economic growth, social cohesion and a corresponding quality of the environment. Most environmental problems are related to human activities aimed at economic growth and securing social cohesion. Consequently, we must find solutions that will satisfy the population's justified requirements to increase the material levels and general quality of life. Environmental technologies, i.e. technologies with minimal environmental impacts, are the principal way to achieve this objective.

Currently, the global community feels threatened by the impacts of climate change. In its climatic and energy package of measures, the EU adopted an ambitious goal to decrease its emissions of greenhouse gases by 20% by 2020 compared to 2005. The decrease should be reached by supporting energy savings and the maximum possible usage of renewable and alternative sources.

The events at the beginning of 2009 showed, however, that **energy security (self-sufficiency) of the EU is an equally important problem** because the EU has to import most of its primary energy sources and this dependency is likely to deepen in the coming years.

In addition to the risk of climate change and the lack of energy security, many EU member states, including the Czech Republic, must face other environmental problems, in particular **air pollution by suspended particles and ground-level ozone, rising quantities of waste, the chemicalization of the environment** etc. A problem that receives less attention but is still of utmost importance is EU **resource security**.

Taking into consideration all of the aforementioned problems, the **importance of environmental technologies** becomes increasingly clear. These are technologies that have a smaller environmental impact than comparable technologies. They consume less energy and resources and generate a lower amount of greenhouse gas emissions and air-polluting substances, less waste water and solid waste.

Although many environmental technologies have already been developed and successfully implemented, there is an immense need for innovative solutions (**eco-innovations**) and the current crisis expands it even further. **The necessary interventions of states into economies** can and should be structured in a way that is **conductive to further development of environmental technologies** and the whole sector of environmental products and services and that **supports economic growth, including the creation of new jobs.**

1.1 | Current environmental protection policies

Environmental protection policy is **the way that a subject treats and plans to treat (over a given period of time) the environment.** The subjects of environmental policy can be supranational groups, individual states or their administrative units, municipalities, private entities (companies or associations of entrepreneurs), political parties and civic associations.

Environmental policy at the national and supranational level involves – in addition to resolving environmental problems themselves – the way the state or group of states wants to contribute to the solution of global environmental problems.

Environmental policy is laid out in a **political document** approved by a competent authority. The political document always contains an analysis of the development so far, the current state and expected outline. Based on the analysis, it determines priorities, quantifiable and non-quantifiable deadlines to reach them and a mix of tools[1]. An inseparable part of the political document is a mechanism for monitoring progress in reaching the policy's goals and for providing potential updates. Wherever possible, the costs of reaching these goals are specified and possible funding sources are mentioned.

1.1.1 | The European Union environmental protection policy

At the EU level, the main political document in the area of environmental policy is the **Sixth Environment Action Programme of the European Community 2002–2012),** approved by European Parliament and Council No 1600/2002 EC of 22 July 2002 for

1 a mix of tools – a complex and optimal set of tools to achieve a given objective (of the environmental policy)

the 2002–2012 period. In 2007, its validity was confirmed until 2012 based on its continuous assessment.

The 6th EAP lays out 4 key priorities in the areas of **climate change; nature and biological diversity; environmental human health and quality of life; natural resources and waste.**

The strategic approaches to reaching the environmental goals of the 6th EAP explicitly contain **support for sustainable production and consumption patterns** and **improving cooperation and partnership between companies with the goal of focusing on sustainable production patterns.** This mainly includes support of an integrated product policy that reflects environmental protection requirements throughout the entire life cycle of products, support of the expansion and utilization of environmentally friendly production processes (technologies) and products and the stimulation of product innovation from the perspective of their environmental impact. Among other steps, the goals and priority areas related to reducing climate change explicitly impacts the support for energy efficiency and the introduction of environmentally efficient methods and technologies in industrial production.

A desirable effect that the implementation of the 6th EAP has and that contributes to fulfilling the concept of sustainable development is the creation of new jobs – **green jobs**[2].

The mid-term review of the implementation of the 6th EAP in 2007 showed that it contributed to the development of the environmental technology sector (eco-industry), which is responsible for 2.2% of the GDP in the EU and employs 3.4 million people.

The integration of environmental concerns into corporate strategies fosters productivity and the innovation potential of companies and creates new market opportunities (e.g. green public procurement[3]). Environmental protection also requires coordinated interdisciplinary research and development focusing on innovations, which was one of the main impulses for the creation of the European Institute of Innovation and Technology.

The recommendations for the future of EU environmental policy imply: *"The Commission and the member states need to continue supporting eco-innovations and environmental technologies because industry can substantially contribute to solving environmental problems. The tool will be a full implementation of the Environmental*

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2 green jobs – employment opportunities in the agriculture, industry, research and development, services and administration sectors that significantly contribute to the protection and restoration of the environment; in particular, they are jobs created in order to protect and rejuvenate eco-systems and biodiversity, to lower the consumption of energy, water and other resources by increasing efficiency and savings, to decrease the emissions of carbon dioxide and other greenhouse gases, to prevent and to reduce all kinds of waste and pollution

3 green public procurement – environmentally friendly public procurement (governmental and public administration bodies preferably purchasing environmentally friendly products and services)

Technology Action Plan and of supplementary measures. The Commission will try to integrate support for environmental products, services and processes into its industrial and environmental policy. In addition, the functioning of voluntary tools in industry (EMAS and environmental labelling), the great potential of which has not yet been fully utilized."

The aforementioned facts suggest that the **6th EAP attributes great relevance to environmental technologies and eco-innovations and that it creates a sufficient framework for their future development and practical implementation.**

1.1.2 | Environmental protection policy in the Czech Republic

The main national political document is **State Environmental Policy of the Czech Republic 2004–2010** approved by Government Resolution No. 235 of 17 March 2004. In the environmental area, the SEP naturally reflects the 6th EAP as well as all other relevant strategic and political documents of the EU, and it is in accordance with them.

The SEP concentrates on four **priority areas: Protection of the environment, landscape and biological diversity; sustainable usage of natural resources, material flows and waste management; the environment and quality of life; protection of the Earth's climate system and the reduction of long distance transmissions of air pollution.** For each of the priority areas, **priority goals, partial goals** and **measures** through which they can be reached are determined.

With regards to environmental technologies and eco-innovations, **the most important priority goals** of the SEP are goal 2.3: **Utilization of renewable resources,** 2.4: **Reduction of the Energy and Material Intensity of Production and Increased Material and Energy Use of Wastes**, 3.5: **Reduction of Anthropogenic/Industrial Impacts and Risks** 4.1: **Reducing Greenhouse Gas Emissions.**

The SEP explicitly mentions **integrated pollution prevention and control** and **the application of best available techniques** as important tools towards achieving these priority goals.

In the SEP section about **sector policies**, support for environmental technologies is primarily mentioned in the **Energy production (support for the introduction of modern high efficiency energy technologies and external costs as low as possible)** and **Industry (to create a programme of support for the general application of low-emission, low-waste and energy-saving technologies with adequate costs and closed production cycles)** chapters.

With regards to **tools for implementing the SEP,** attention is devoted – in addition to standard legal (normative) and economic tools – to **voluntary tools (labelling, environmental management systems, cleaner production, eco-design, voluntary agreements, green procurement)** and to **research and development (to support the research of technologies and equipment for protecting and improving the environment and for sustainable development).**

The aforementioned facts suggest that the **State environmental policy of the Czech Republic 2004–2010 provides a sufficient general framework for supporting the development and application of environmental technologies and eco-innovations.**

1.2 | Policy of support for environmental technologies and eco-innovations

In accordance with Chapter 34 of Agenda 21[4], **environmental technology** is defined **as a technology whose environmental impact is smaller than a technology that is comparable in other regards.**

Thereafter, the **environmental goods and services industry** (eco-industry) is defined as **activities producing goods and services whose goal it is to measure, prevent, limit, minimize or rectify environmental damage, be it in the climate, water, air or land, as well as with problems related to waste, noise and eco-systems.**

For practical reasons, it is appropriate to distinguish between environmental technologies of the first generation (primary) and the second generation (secondary). **Environmental technologies of the first generation (end-of-pipe[5]) are technologies whose only or main purpose is to reduce environmental impacts.** Environmental technologies of the first generation are operated either on a stand-alone basis (municipal waste water treatment plant) or are a part of a larger technological unit (desulphurization plant). The development and application of environmental technologies of the first generation are, to a decisive degree, a result of legal requirements. Environmental technologies of the first generation can be clearly defined.

Environmental technologies of the second generation are technologies that are primarily used in the production of goods or in the delivery services but have

4 Agenda 21 – a programming document of the UNO approved at the Rio de Janeiro conference in 1992

5 end-of-pipe technologies – end technologies that are used for handling waste and pollution (e.g. separators, waste water treatment plants, landfills, incineration plants, waste treatment plants) and are not an indispensable part of the production technology

significantly lower environmental impacts than comparable technologies. The production and application of environmental technologies of the second generation are also strongly motivated by legal requirements. Compared to technologies of the first generation, however, economic motives (i.e. the necessity to utilize resource and energy outputs more efficiently) play a more prominent role. For environmental technologies of the second generation, the definition can be complicated in some cases.

The best defined category of environmental technologies is best available techniques. They are also mentioned in legal norms. According to Section 2(f) of Act No. 76/2002 Coll., on integrated prevention, the best available techniques are the most efficient and most advanced technologies and methods of operating them that demonstrate a practical value of certain technologies designed for preventing emissions and their environmental impact or, if prevention is not achievable, for their reduction.

At the EU level, BAT for selected industrial and agricultural activities are defined and qualified in Best Available Techniques Reference Documents.

In the new draft of the Directive on industrial emissions, which will include and replace the existing Directive 96/61/EC concerning integrated pollution prevention and control, the scope of the binding character of BAT and the reference documents and their efficiency in the process of issuing integrated permissions may be strengthened.

For evaluating and assessing individual environmental technologies, it is necessary to consider the entire life cycle, which is the most objective of the available criteria for evaluating the environmental impacts of a specific technology, product or service.

Eco-innovation is a special case of innovation that can be defined as a process of establishing new knowledge and its transformation into useful products, services and technologies for the domestic and international markets, which leads not only to the creation of economic value, but also to an increase in the quality of life.

Eco-innovation is thus **any form of innovation aimed at achieving significant and demonstrable progress in the area of sustainable development so that environmental impact is reduced, or a much more efficient and more responsible utilization of natural resources, including energy.**

Most member countries of the EU and OECD have started considering eco-innovation as a way of reaching environmental goals and of increasing the competitiveness of domestic companies. Eco-innovation creates new opportunities for entrepreneurial activities in all areas of the economy, especially energy production, construction, industry, transport and logistics, agriculture, the food industry, the travel industry, the mining industry, waste and water management and environmental protection itself. In addition to these areas, the OECD expects eco-innovations in the “green” chemical industry that are mainly based on biotechnologies and biomass as well as on retaining and storing CO_2 from incineration. An objective of eco-innovation can be both existing and newly developed environmental technologies of the first and second generation.

1.2.1 | Tools for supporting environmental technologies and eco-innovations

The tools for supporting environmental investments and eco-innovations are – like tools of environmental policy in general – categorized into the following groups:
- normative (administrative) tools,
- economic and market tools,
- organizational and institutional tools,
- informational tools,
- voluntary tools,

In the area of normative (administrative) tools, the most important impulse for developing and applying environmental technologies are limit values for pollution sources (emission limits, standards, technical requirements for operating equipment) identified in legal norms. Standards of environmental quality are indirectly important as well (pollution limits, requirements for water quality).

Among the normative tools, **the principle of integrated prevention and pollution reduction** has an extraordinary role. It makes it possible – to a considerable extent – to set individual conditions for operating equipment so that environmental impacts are reduced. This approach can lead to the installation of new environmental technologies as well as to an increase in the efficiency of the current technology.

In the Czech Republic, the following **normative (administrative) tools** are mainly used to support environmental technologies and eco-innovations:
- limit values for pollution sources (e.g. emission limits for sources of air pollution),
- global standards of environmental quality (e.g. pollution limits, requirements for water quality),
- product standards (e.g. fuels, packaging),
- obligations for handling certain commodities (e.g. chemical substances and agents, GMO, selected types of waste, packaging),
- obligations for handling energy (e.g. pursuant to the Act No. 406/2000 Coll. on energy management),
- technical requirements for operating equipment (e.g. sources of air pollution, sources of water pollution, landfills, large industrial complexes),

- permits to operate equipment and to conduct activities influencing the environment according to the relevant laws on components of the environment (e.g. the Act on air protection, the Act on water, the Act on waste),
- integrated permission (pursuant to the Act on the integrated prevention),
- quantitative requirements at the national level (e.g. the Kyoto obligation, national emission ceilings, reduction in the quantity of biologically degradable waste deposited into landfills).

Economic tools are applied both directly and indirectly, and as positive and negative stimuli. Direct financial support (positive stimulus) occurs mainly in the public sector by channelling money flows so that they encourage the spreading of environmental technologies in facilities operated by the public sector and a higher demand on the public sector for environmentally beneficial products and services and for eco-innovation. An important stimulus is the appropriate management of state funded research and development projects. Support from public sources can at last be provided to citizens (e.g. subsidies for changes to heating or building insulation).

Crucial economic tools are environmentally friendly public contracts that can strongly encourage the development and application of environmental technologies and create a market with eco-innovations. The entire life cycle of the technology, products and services can be considered in the decision-making process.

Indirect economic stimulation (positive as well as negative) focuses only on the private sector respecting the principle that, in general, it should support the installation of environmental technologies (especially in areas that are not governed by normative tools) and to fill the gap between the legal requirements and the possibilities of advanced environmental technologies. In practice, they can be accelerated depreciation, classifying a larger share of investment into science and development into eligible costs for tax purposes, the possibility of creating a reserve for future environmental investments, reduction of a lower VAT rate or waiving fees for pollution of the environment or their parts.

The tools of economic stimulation are prominent in the area of energy production from renewable resources and to a lesser degree in the production of heat from renewable resources.

Indirect support can be used for making environmentally beneficial products and services more attractive to citizens (e.g. a lower VAT rate).

In the Czech Republic, the following **economic** tools are used to support environmental technologies and eco-innovations:

- tax relief (e.g. a lower VAT rate for bio-fuels, VAT tax exemption for research and development projects, eligibility of science and research expenses for tax purposes, exemption from tax for solid fuels),

- tradable emission allowances (according to the EU ETS system),
- support of energy production from renewable resources (pursuant to the Act No. 180/2005 Coll. on the support of energy production from renewable energy resources),
- environmental payments (fees for polluting air and water, fees for depositing waste into landfills),
- direct financial support (in particular the state budget, the State Environment Fund of the Czech Republic, EU funds – Operational Programmes).

Considering that a persistent problem of eco-innovation development on the supply side is a low level of cooperation between the private sector and public organizations involved in research and development, it is absolutely necessary to strengthen or create supporting tools. While economic tools can be applied in the private sector, for organizations involved in science and research, it is advisable to reflect desirable activities when evaluating the performance and subsequent allocation of funds, namely through institutional and organization tools. Public support for establishing and operating of scientific laboratories and technology parks (centrally as well as at the regional and local levels) is also of great importance. A very important administrative tool is verification of environmental technologies, which is a fundamental condition for deciding about potential support. At the EU level, cooperation between the public and private sectors based on specialized platforms seems to be very successful.

In the Czech Republic, the following **organizational and institutional tools** are used to support environmental technologies and eco-innovations:

- programmes and concepts (e.g. Programme of Support for Environmental Technologies in the Czech Republic, National Innovation Strategy, National Innovation Policy, Fundamental Long-Term Research and Development Trends, National Research Programme, programmes of individual ministries),
- the purchase of environmentally friendly products (pursuant to Government Resolution No. 720 on the proposal to support the development of the sale and usage of environmentally friendly products of 19 July 2000),
- supporting structures and mechanisms for the application of voluntary tools (labelling, systems of environmental management).

Information tools include the obligation to acquire, process and submit information about the state of the environment and about the influences on it (monitoring the state of the environment, EIA, information about environmental properties of products) as well as purposeful work with information (education and awareness).

In the area of environmental technologies, the process of environmental impact assessment (EIA) is very importance. During this assessment, the conditions for operating the facility can be determined. While this is a soft tool (in theory, the construction can proceed despite the negative assessment), recommendations from the EIA process are almost always respected in the practice.

As regards the support of eco-innovations, education and awareness are extremely important (both in the public sector and in the whole population) because in this way, demand for environmentally beneficial products and services can be stimulated and a market with eco-innovations can be created.

In the Czech Republic, the following **informational tools** are used to support environmental technologies and eco-innovations:

- environmental impact assessment (EIA),
- monitoring and evaluating the state of environment,
- environmental education and awareness (in particular the State Programme of Environmental Education and Awareness),
- specialized information tools (e.g. a database of environmentally harmful support measures).

Voluntary tools are the most important informational, moral and economic kind of support for environmentally friendly products and services because they raise the interest of producers in environmental technologies and in eco-innovations and they stimulate the establishment and development of the environmental market, because producers naturally promote their products and thus encourage demand. Environmental education and awareness are of utmost importance.

Voluntary tools include systems of environmental management (EMAS, ISO 14000), cleaner production, eco-design, evaluation of life cycle and voluntary agreements between the private sector and public administration.

In the Czech Republic, the **following voluntary tools** are used to support environmental technologies and eco-innovations:

- labelling (national labelling system),
- systems of environmental management (EMAS, ISO 14000),
- projects of cleaner production,
- voluntary agreements.

1.2.2 | The current situation in the area of supporting environmental technologies and eco-innovations at the European Union level

The main political document in the area of supporting environmental technologies and eco-innovations is the **European Technologies Action Plan of the European Union** proclaimed in an announcement of the European Commission addressed to the Council and European Parliament of 28 January 2004 and approved by the Council in March 2004.

On the one hand, the ETAP reflects the requirements of the environmental policy anchored in the 6th EAP and on the other hand, it refers to a general concept of sustainable development and on the Lisbon Strategy[6].

ETAP aims at using all available potential of environmental technologies to mitigate the pressure on natural resources, to improve the quality of life of Europeans and to stimulate economic growth.

The main goal of the ETAP is, consequently, **to remove obstacles for development and to introduce environmental technologies.** One of the **crucial ways to reach this goal is to support eco-innovations,** including supporting the access to small and medium-sized innovative enterprises towards venture capital. The ETAP imposes requirements on the EU member states with the goal of increasing the support of eco-innovations, among other measures, by national programmes generally aimed at supporting research and development or by other (e.g. financial) tools.

The general ETAP priorities are **a Shift from research towards the market, an Improvement in market conditions** and a **Global activity.** To fulfil them, the ETAP contains 28 tasks with deadlines, of which member countries are explicitly required to complete 19.

The ETAP also contains examples of "good practice" in integrated policy, a partnership between the private and public sectors in the area of research and development, the spreading of information, demonstration projects and green public procurement.

The ETAP Implementation Report for 2004 requires that member states prepare national programmes for supporting environmental technologies.

In recent years, the relevance of the ETAP has been strengthened by the EU ambitions in the mitigation of the climate change impact by the package of climate and energy measures[7].

In addition to ETAP, another important tool for supporting the development of environmental technologies and eco-innovations is **the 7th Framework Programme for Research and Technological Development** for 2007–2013 and activities supporting the partnership of the public sector, namely the **Joint Technology Initiatives** and **European Technology Platforms.** More or less explicitly declared support for eco-innovations is also included in many other EU programmes, e.g. the Eco-Innovations programme of the European Union.

6 Lisbon Strategy – the main document for the social and economic modernization of the EU and for the restoration of the environment approved by the European Council in March 2000

7 the package of climate and energy measures – a set of measures proposed by the European Commission for the area of energy and climate protection at the beginning of 2008

1.2.3 | Environmental technologies in the Czech Republic

With regard to the application of environmental technologies, the existence of the independent Czech Republic can be divided into two periods: Before 2000, technologies of the first generation clearly prevailed due to the obligations imposed by environmental legislation. Since 2000, the share of technologies of the second generation started increasing, which is partly related to the investment cycle of the current technological facilities and to investments into new technological facilities. The implementation of Act No. 76/2002 Coll. on integrated prevention also greatly contributed to the application of environmental technologies. During the implementation, technologies of more than the one thousand most important industrial and agricultural businesses were compared to BAT and environmental requirements for newly constructed facilities were identified.

In quantitative terms, the situation for the application of environmental technologies can be best evaluated with the help of **total investments into environmental protection**, whose magnitude is monitored by the statistical office. It is further classified into the **protection of air and climate; the handling of waste water; the handling of waste; the protection and remediation of land, underground and surface water; the reduction of noise and vibrations; the protection of biodiversity and landscape; the protection against radiation; research and development.** The share of total investment into environmental protection in the GDP of the Czech Republic between 1993 and 2006 is depicted in Table 1:

TABLE 1 | The share of total investment into environmental protection in the GDP of the Czech Republic [%], 1993–2006

Year	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
GDP share [%]	2.00	2.50	2.20	2.20	2.24	1.76	1.39
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
GDP share [%]	0.98	0.85	0.61	0.75	0.73	0.61	0.70

SOURCE | Czech Statistical Office

Note: The relatively high GDP growth between 2000 and 2006 should be taken into consideration when interpreting the data in the table.

The highest share of total investment, roughly 80%, occurred in the area of protecting climate and air and the handling of waste water. Investments in technologies of the first generation clearly prevailed. In the case of waste water, they are of a systemic nature. With regards to air, most innovations occurred before 2000. Examples of important investment into environmental technologies of the second generation in the area of air protection before 2000 are the extensive programme of installing gas delivery equipment in municipalities and support for renewable energy sources.

As with supranational organizations and with most developed countries, **the Czech Republic has a strong interest in supporting the development and application of environmental technologies.**

In Government Resolution of February 22, 2006 No. 181, the government of the Czech Republic approved **the Programme of Support of Environmental Technologies in the Czech Republic (hereinafter only "Programme")**, which was prepared based on a recommendation of the European Commission that the member states should prepare national plans of ETAP implementation.

The objective of the programme is defined as **the coordination of support of environmental technologies** and **a contribution to ETAP implementation** under the assumption that specific measures will be reflected into the policies and programmes of individual ministries. The Programme focuses on the maximum possible utilization of the potential offered by environmental technologies with the goal of reaching as high a reduction of the environmental impact as possible.

In the Programme, **environmental technology** is defined as **a technology whose usage causes less damage to the environment than the usage of comparable alternatives.**

The **National Policies and Strategies** chapter of the Programme features a brief characterization of several important strategies and political documents as to the possibility to support development and application of environmental technologies. They are: Strategy of Sustainable Development of the Czech Republic, Strategy of Economic Growth of the Czech Republic, National Reform Programme, National Innovation Strategy, National Innovation Policy, Long-Term Trends of Research and Development, State Environmental Policy of the Czech Republic, Resource Policy of the Czech Republic, State Energy Concept of the Czech Republic, Industrial Policy of the Czech Republic, Concept of Pro-Export Policy, Concept of Consumer Policy, Transport Policy of the Czech Republic, Framework for Sustainable Production and Consumption of the Czech Republic.

An analysis of the 14 aforementioned strategy documents implies the following:

In the Czech Republic, there is both the will and space for supporting all relevant aspects of developing and implementing environmental technologies. The most important downside is, however, the low degree of coordination, which, in turn,

justifies the preparation of the Programme. As a part of the Long-Term Trends of Research and Development, individual ministries **support** both **activities in the area of material and process research** and **activities focusing on the research of new applications for renewable energy sources. The greatest weakness in the Czech Republic is the low ability to put the results of the research and development into practice**, which is caused by a low degree of cooperation between universities and other research institutions with the private sector on one hand, and by a low number of technology-oriented companies (in particular small and medium-sized ones since large firms typically run their own research and development departments) on the other hand.

Concerning the possible **tools for supporting environmental technologies**, the Programme mentions environmentally friendly public procurement, reducing support harmful to the environment, ecological tax reform, fees for protecting the environment, guaranteed energy services, energy benchmarking, environmental funds, price regulation, support from public budgets, integrated prevention and reduction of pollution, systems for environmental management, cleaner production, labelling, eco-design, evaluating the life cycle, voluntary agreements, education and raising awareness, international cooperation.

Most of these tools have been or are being applied in the Czech Republic. To implement the Programme, **15 specific measures** have been proposed. 3 of them are of an ongoing nature, while 11 were supposed to be carried out by the end of 2006 and one by June 2007.

- as a part of the National Research Programme III, to shift the focus of research to environmental technologies in an adequate fashion,
- as a part of measure No. 3 of the National Innovation Policy, to shift the focus of research to environmental technologies in an adequate fashion,
- to analyze the current legislation in the area of public budgets and to propose measures leading to a higher representation of green public procurement,
- to analyze the potential for using green public procurement, including the preparation of systems for monitoring the related data,
- to submit rules for green public procurement for the entire public sector,
- to issue a methodology governing the definition of environmentally friendly products and services, in particular in connection with Government Resolution No. 720 on the proposal of support for developing the sale and usage of environmentally friendly products of 19 July 2000),
- to adopt rules for assessing the environmental impact of public support with the goal of reducing support where the impact is negative,
- to conduct random regional surveys of the environmental impact of public support,

- to analyze the existing experience and to adopt measures leading to a more extensive usage of energy contracting in the Czech Republic as a part of the State Programme of Support for Energy Savings and the Usage of Renewable Energy Sources,
- to propose indicators to evaluate the level of support for environmental technologies,
- in connection with the implementation of the directive on taxation of energy commodities, to propose a system of energy benchmarking for energy-intensive products and technologies,
- to issue methodology instructions on the use of managerial accounting to support the objectives of the sustainable development strategy,
- to evaluate the experience with fulfilling Article 6 of Directive 2001/77/EC of the European Parliament and Council,
- to strengthen environmental criteria in Structural Funds in the outline for 2007–2012,
- to analyze the possibility of establishing environmental funds and to propose their content in the conditions of the Czech Republic.

Despite its relative vagueness, the programme succeeds in describing the situation in the area of support of environmental technologies in the Czech Republic until 2005, and it serves as a framework for follow-up activities.

The Ministry of the Environment was asked to **evaluate the material progress of the Programme** once a year in cooperation with the relevant ministries and to submit it to the government once every two years. At the end of 2008, the government of the Czech Republic received its first evaluation material, "**The Continuous Evaluation of the Programme of Support of Environmental Technologies in the Czech Republic" (hereinafter only "Continuous evaluation"),** which contains **examples of specific measures that contributed to the support of the environment throughout the period under question** (the production of heat using bio-fuels, utilization of alternative fuels in transport, intensification of bio-gas production, integrated prevention and reduction of pollution). The Continuous evaluation also features **ways of supporting environmental technologies**, namely the Support of Research and Development, Environmentally Friendly Public Procurement, Defining Environmentally Friendly Products, Evaluating the Environmental Impact of Public Support, Utilising Energy Services, Indicators for Evaluating Support, Energy Benchmarking System, Managerial Accounting of Sustainable Development, Experience with the Support of Renewable Energy Sources, Environmental Criteria for Structural Funds, Environmental Investment Funds.

The Continuous evaluation shows that **ways of supporting development and application of environmentally beneficial technologies in the Czech Republic are varied, as is the degree of their success.** Demonstrable progress has been reached in the areas of Production of Heat Using Bio-Fuels (preferential tax treatment), Utilization of Alternative Fuels in Transport (adding a bio-component to fuels), Integrated Prevention and Reduction of Pollution (issuing integrated permits for existing facilities), Production of Support and Development (MoE, MoA, MIT, MT, MEYS), Purchase of Labelled Products by Central Government Bodies (share in purchase of 27%), Introduction of Environmental Management Systems (33 organizations certified according to EMAS, roughly 3 500 organizations certified according to ISO 14001).

For the coming period, the Continuous evaluation **suggests that the following areas should be paid more attention:**

- **the package of energy measures** (energy savings / energy efficiency, local energy production and efficient energy distribution),
- **the package of climate and energy measures** (reduction of greenhouse gas emissions and increase in the share of renewable resources, adaptation of mechanisms for trading emission allowances to the amended version of Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading).
- **sustainable transport** (emission limits for carbon dioxide for new cars, usage of tires with a low rolling resistance),
- **some EU strategies** (Action Plan of Sustainable Consumption and Production and Sustainable Industrial Policy)
- **innovative environmental technologies** (the second generation of bio-fuels, hybrid automobiles, technologies for retaining and storing CO_2, bio-plastic, membrane technologies for water filtration, utilization of solar technology for air-conditioning, decentralized water handling, automatic separation of raw materials from waste),
- **innovations in construction** (construction materials, constructions, efficient heat transmissions).

1.2.4 | Eco-innovations in the Czech Republic

If the Czech Republic prepared and is implementing the necessary supporting activities for environmental technologies, it is at its very beginning of support for eco-innovations. **There are problems on the sides of both supply and demand.**

The greatest problem on side of demand for eco-innovation is the fact that **the public sector**, whose expenditures represent about 30% of the total final consumption, **does not demand environmentally beneficial products or services to a sufficient degree.** The problem is even more pronounced for households, whose share in the total final consumption amounts to almost 70%. Citizens who would be potentially interested in eco-innovative activities and potential consumers do not have sufficient market impulses.

According to analyses, the following are the most important barriers of the supply of eco-innovations:

- **the state support for eco-innovations is not systematic, effective and coordinated,**
- **the cooperation between research and development institutions and the private sector is not sufficient,**
- **the absence of venture capital and economic stimuli (subsidies, taxes, amortization),**
- **a lack of human resources with the required specialization and the necessary degree of flexibility.**

The ongoing evaluation specifies the following **priority areas of the potential support for eco-innovations:**

- the second generation of bio-fuels,
- hybrid automobiles,
- technologies for retaining and storing CO_2,
- bio-plastics,
- membrane technologies for water filtration,
- utilization of solar energy for air-conditioning,
- decentralized handing of water,
- automatic separation of raw materials from waste,
- new construction materials,
- efficient transmission of heat.

1.2.5 | Outline for the next period in the Czech Republic

At the beginning of 2009, the MoE prepared **a document on the update of the Programme (hereinafter only "Update")**, which was discussed and approved by the MoE on April 10, 2009. The document **stresses the issue of eco-innovations and the suggested measures reflect the impact of the global financial and economic crisis.**

For next period, the Update proposes **priorities for reducing the emissions of greenhouse gases and air-polluting elements** (with an emphasis on the integrated approach)**, the reduction of the quantity of produced and discharged waste water, a decrease of the quantity of produced waste and the repeated use of waste.** The **sector priorities** are **energy production, transport** and the **manufacturing industry.** The Update proposes **18 specific measures** at four levels of public administration.

1. Measures requiring new legislation or amendments to the law:

- to set parameters of the tax and fee systems so that they support the development and increase in the efficiency of environmental technologies and to stimulate demand for environmentally friendly products and services,
- to increase the share of purchased environmentally friendly products and services in public procurement.

2. Measures requiring the approval of the Government (decrees, government resolutions):

- to increase the energy efficiency in production and consumption,
- to support carbon-free or low-carbon technologies,
- to support the utilization of renewable energy sources in the production of heat and in heating.

3. Measures requiring an agreement between two or more ministries:

- to strengthen environmental criteria in Operational Programmes,
- to support more extensive utilization of energy contracting in the Czech Republic as a part of the State Programme of Support for Energy Savings and Usage of Renewable Energy Sources,
- to propose a benchmarking system for environmentally relevant (in particular energy- and resource-intensive) products and technologies, taking into account the LCA,
- to set priorities for eco-innovations in implementing the National Research Programme III,
- to place greater emphasis on cooperation with the commercial sector in the system of R&D support in general and in particular in the area of eco-innovations,
- to support the mobility of people involved in R&D among various research organizations and businesses in the area of eco-innovations,
- to create a system of support for funding test phases of eco-innovations and the first (reference) versions of eco-innovative technologies,
- to increase the availability of capital for eco-innovative projects of small and medium-sized businesses,
- to give an impulse to the establishment of an interest group (cluster) representing the sector of environmental technologies and eco-innovations,
- to create a generally accessible registry of R&D projects for eco-innovations.

4. Measures at the discretion of the MoE:

- to maintain a registry of selected environmentally harmful public support in the Czech Republic,
- to develop tools and to secure a sufficient structure, expert and organizational capacity for assessing and verifying environmental technologies,
- to prepare indicators for assessing and verifying environmental technologies based on the unified European system of Environmental Technology Verification, taking into account the LCA.

The approval of the measures proposed in the Update will have a substantial positive impact on the fundamental elements of the environment because it will decrease the resource and energy dependency of the economy and decrease the emission of greenhouse gases (in particular CO_2) and of air-polluting substances, reduce the quantity of discharged waste water and of produced waste. This way, it will help to fulfil the international obligations that the Czech Republic accepted or plans to accept in the environmental area (especially the obligations following from the package of climate and energy measures or national emission ceilings for some polluting substances). **In addition, the proposed measures will strengthen the energy and – in part – resource sufficiency of the Czech Republic.**

From the economic point of view, the approval of the proposed measures will strengthen the desirable (and, to a considerable degree, missing) cooperation between R&D institutions and the private sector and will thus shift the Czech Republic closer to a knowledge-based economy. In addition, we can expect that new jobs will be created by strengthening the segment of small and medium-sized companies.

Many of the proposed measures in the Update will also mitigate the impacts of the current economic crisis. They are mostly measures focusing on stimulating the demand for environmentally friendly products and services, on increasing the energy efficiency and utilizing renewable energy sources, developing new technologies, strengthening R&D institutions and their cooperation with the commercial sector and funding the development of eco-innovation and facilitation of their transfer into the practice.

Environmentally Friendly Generation of Heat and Electric Energy

2

2 | Environmentally Friendly Generation of Heat and Electric Energy

The mining of fossil fuels, which are a basic element for producing heat and electric energy, negatively impacts the environment. The fossil fuels utilization is a primary source of greenhouse gas emissions, and as a result of air pollutant emissions, it also negatively impacts human health, soils and forest stands. Resources of primary raw materials for energy are constantly getting smaller.

The Czech Republic places emphasis on the sustainable development of energy, namely with what technology and with what consequences for the environment that all energy generation process will have. **Reduction of the emissions of particulate matters and desulphurization, and eventually denitrification of thermal power plants and large heat stations have already occurred in the Czech Republic. Today, innovations in equipment are happening at a rapid pace. The purpose of these innovations is to reduce emissions through more efficient generation.**

However, none of these measures will eliminate the negative influences of the generation of electricity and heat on the environment from the long-term point of view. **Another purpose of these innovations is,** therefore, **to ensure that greenhouse gas concentrations in the atmosphere become stabilized at a level that would not be hazardous either to mankind or to the climate[1].**

Considering the purposes that are specified for the area of energy in the State Environmental Policy of the Czech Republic, energy sources that either have no or only a negligible negative influence on the environment are becoming more important. This includes nuclear energy and renewable energy sources: including the energy from water, wind, sun, biomass, biofuel and geothermal energy.

1 decreasing the consequences of mankind's activities on Earth's climate – restriction in increasing the average temperature of the Earth by 2 °C by 2100

2.1 | Fuel cells and hydrogenous power engineering

Fuel cells are any electrochemical devices that produces electricity. They **allow for a more effective and flexible use of fuels**, including natural gas, biogas, hydrogen and methanol. They are supposed to be used mainly in transport and power engineering, where they could **replace classical combustion engines**. Fuel cells can serve as stand-by units in hospitals, army equipment and remote locations.

Being based on actual predictions, fuel cells using gas from gasified coal will play a key role in power engineering in the future. The forecasts stem from these sources being 60% more efficient and having only 10% of the emissions of currently used technologies, plus the possibility of CO_2 capture and disposal in accordance with the technologies being newly developed (see Chapter 2.5 – Technology for CO_2 capture and storage). The development and implementation of this technology already exists in the first quarter of the 21st century. In the Czech Republic, fuel cells are being developed and tested at universities. Examples include the Faculty of Electrical Engineering of CTU, the Department of Inorganic Technology of the Institute of Chemical Technology and elsewhere.

Changes to hydrogen power engineering, which could help resolve the problem with the storage of electricity and heat, is being studied intensively. However, today it is just a vision, not a commercially available solution.

2.2 | Electricity generation from renewable energy sources

One of the first indicative obligations of the Czech Republic in the Treaty of Accession to the EU of 2004 was to specify a share of electricity generation from renewable energy sources in the total gross consumption of the Czech Republic at an amount of 8**%** by 2010. At the end of 2007, this proportion was 4.74**%.** It is evident that the Czech Republic focuses its attention and support on RES. The main reason for supporting energy generation from RES is its significance for reaching the sustainable development of energy. Table No. 2 shows a summary of electricity generation from RES.

TABLE 2 | **Electricity generation from RES in the Czech Republic [MWh, %], 2007**

Renewable electricity source	Gross generation of electricity [MWh]	Electricity delivery to the supply network [MWh]	Share in home gross consumption of electricity [%]	Share in gross generation of electricity [%]
Hydro power plants	2 089 600.0	2 080 800.0	2.90	2.37
Biomass in total	968 062.9	403 706.1	1.34	1.10
Biogas in total	215 223.0	138 485.0	0.30	0.24
Municipal solid waste (MSW)	11 975.1	5 074.0	0.02	0.01
Wind power plants	125 100.0	124 700.0	0.17	0.14
Photovoltaic systems (estimate)	2 127.0	1 800.0	0	0
Liquid biofuels	9.0	8.2	0	0
RES in total	**3 412 097.0**	**2 754 573.3**	**4.73**	**3.86**

SOURCE | MIT

The theoretical potential of electricity generation from RES is 50 TWh in the Czech Republic. 5% of this 50 TWh would be from hydraulic power plants, 12% from wind power plants, 20% would be geothermal energy, 26% from biomass energy and 37% from solar energy. The actual potential, influenced mainly by economics and available locations for these sources, is lower.

2.2.1 | Hydro power plants

Hydro power plants are the most expandable facilities for energy generation from RES in the Czech Republic. Their **advantage is their flexibility and quick start thanks to the accumulation of water energy in reservoirs**. Therefore, **they significantly contribute to maintaining the balance between the generation and consumption of electricity in energy grids.**

The share of HPP in electricity generation from RES fluctuates; generation is strongly dependent on watercourse accumulation throughout the year. Today, the annual volume of electricity deliveries from HPP hover around 2.5 TWh per year in the Czech Republic. The construction of large dams significantly impacts the landscape and local ecosystems, and it changes microclimatic conditions in surrounding areas. Therefore, it is impossible to assume a considerable increase in the number of large HPP in the future.

However, **the development of technologies for small water heads and direct flow[2] micro and small HPP, which do not significantly influence waterways and water wildlife, is being supported**. Thus, water energy is an energy source being looked at by small investors to deliver electricity. These projects are eligible for financial allowances known as green bonuses.

In addition to large HPP (above 10 MW), **536 small HPP exist in the Czech Republic, and this number is still increasing**. ČKD Blansko Holding a.s., delivers turbines not only in the Czech Republic, but throughout Europe, Asia and America. It is one of the most prominent producers of turbines and equipment for small HPP. The company produces all types of turbines. The company also has its own research department studying water equipment and a hydraulic testing department. There are only a handful of organizations in this field worldwide.

2.2.2 | Wind power plants

At the end of 2008, the Czech Republic had 149.7 MW of electricity from wind power plants. Based on the number of filed applications for assessing environmental impacts, **it is anticipated that further development will continue in the coming years. It is a popular energy source with a short construction time** for investors.

Interrupted energy generation is a considerable disadvantage of WPPs (wind power plants). With a large concentration of WPPs, the stability of transmission systems can be endangered. This is known as “blackout”[3]. Thus, it is therefore important that WPPs have a total redundant classical source of electricity generation. Solutions are being sought by joining WPPs with storage networks, by connecting WPPs to “intelligent networks” (see the Chapter 2.7 – Intelligent network development) and in intensifying international interconnections of energy systems. Under these circumstances, WPPs would become potential sources of generation.

Today, WPPs are being constructed throughout the entire Czech Republic. Both large corporations such as ČEZ, a.s. and JT Group s.r.o. and small entities are investing in this technology. As of June 2008, 52 WPPs were installed. Current projects include Pchery in Kladensko (2 x 3 MW), a wind park in Stříbro in Tachovsko (13 x 2 MW) and in the surroundings of the Dukovany nuclear power plant of (9 x 2 MW).

2 direct flow water power plants – water power plants located right in the water course
3 blackout – a total interruption of electricity supplies on a large scale

2.2.3 | Biomass combustion

The combustion of wood and vegetable materials, mainly sawdust, wood chips, cellulose extracts and waste timber, both separately and together with fossil fuels for producing electricity and heat, is understood as the energetic use of biomass. Biomass is a renewable source that will significantly contribute to fulfilling the objective of achieving an 8% share of electricity generation from renewable sources in the gross final consumption in the Czech Republic by 2010. Large energetic and ecologic expectations are connected with biomass.

Of all renewable sources, it has the greatest potential for technical use over the short horizon in the Czech Republic.

Co-combustion of biomass and coal in large power plants with a share of biomass up to 30% has proven useful on a large scale. Coal heat and power plants count on the use of biomass with a co-combustion share up to 50% after technical adjustments.

Medium and large combustion sources significantly share in the combustion of biomass; 186 combustion sources were registered as of June 2008. Nevertheless, some **technologies being used are unique. An example is the thermal oil boiler for wood chips with an ORC[4] module** being used by Žatecká Teplárenská a.s. The boiler uses organic hydrocarbons instead of classical water steam for driving its turbine. Oil heated to nearly 300 °C is the source of hydrocarbons. The technology shows **minimal emissions of contaminants into the atmosphere compared to combustion equipment of the same output**.

If biomass is burnt correctly, it is **the most ecologically friendly fuel**. NO_x created in the presence of atmospheric air combustion is the only atmospheric contaminant.

4 ORC – The Organic Rankine Cycle; an electrical condensation cycle using a mixture of organic compounds (silicon oil), whose thermodynamic characteristics are suitable for use in the thermal cycle. This is instead of steam as the primary substance

TABLE 3 | **Energetic exploitation of biomass in the Czech Republic [t], 2007**

Fuel	For electricity generation	For heat generation	Total
Wood waste, wood chips, sawdust etc.	402 987	934 669	1 337 656
Firewood	–	54 635	54 635
Plant materials	16 220	22 260	38 480
Briquettes and pellets	24 321	15 529	39 850
Cellulose extracts	221 563	888 915	1 110 478
Other biomass	286	192	478
Total	**665 377**	**1 916 200**	**2 581 577**
Estimation of household wood consumption			3 585 103
Export of biomass suitable for energetic purposes			591 740
Energetically exploited or exported biomass in total			**6 758 420**

SOURCE | MIT

A suitable combustion technology is produced, for example, by the company Jaroslav Cankař and son ATMOS. Their wood burning boilers allow for biomass combustion and wood gas production. Gaseous components (wood gas) are released from the biomass due to high temperatures. These are further heated without the access of air in combustion space and burnt as a gaseous fuel. A portion of generated heat is used for additional biomass gasification. Depending on the quality of the fuel, the boiler shows a higher efficiency (81–89%) than traditional combustion (70%) and produces minimal emissions. The ATMOS boilers comply with the limits for obtaining the Environmentally Friendly Product label and comply with requirements of the Green for Savings subsidy programme.

2.2.4 | Photovoltaic power plants

By 2050, direct transformation of solar radiation into electrical energy in photovoltaic panels is **considered as the technology with the greatest potential for producing energy from RES**, although its development requires the greatest subventions now. This technology does not need any fuel for its output, it does not emit any airborne release contaminants, and it does not include a rotary system, a normal source of failure and noise. All of these factors are typical for other equipment that produces energy from RES.

Today's output from photovoltaic power plants is rapidly increasing when compared to its market share during the preceding year. In 2007, the output represented about 5.4 MWp[5], whereas at the end of 2008, it was already 54.7 MWp.

PVPPs significantly contribute to environmental protection. The Bušanovice I and II PVPPs save 1 500 tons of CO_2 emissions a year compared to the electricity produced by thermal power plants.

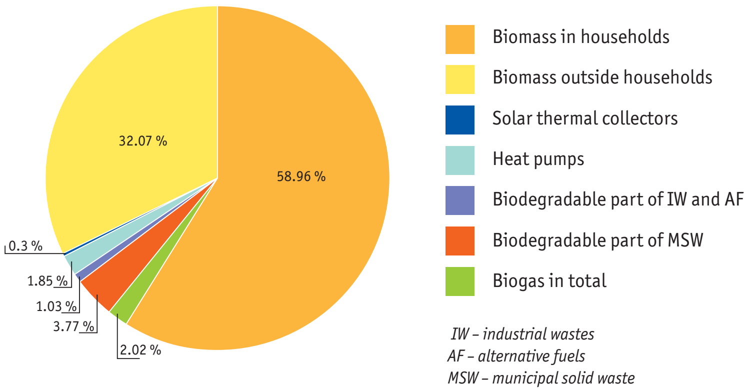
2.3 | Renewable energy sources use for heating and cooling deliveries

The Czech Republic consumes between 1 100 and 1 200 PUs (generation unit) for providing heat to industry and households. 50 PUs are used by households and the rest by industry and others.

RES energy also shares in deliveries of centrally supplied heating. Biomass, biogas and geothermal heat from heat pumps are used both for larger systems for supplying heat and for small systems or single-home systems. In contrast, solar collectors for hot water heating are almost exclusively used for individual buildings and single family houses.

5 MWp – megawatt peak; unit of peak output being supplied by the solar equipment under ideal conditions (clear day)

GRAPH 1 | **Structure of heating generation from RES in the Czech Republic [%], 2007**



SOURCE | MIT

While some systems for delivering heat from RES are commercially available and are being used (solar panels and collectors for water heating, wood heaters, biogas combustion), **RES use for cooling also exists in the Czech Republic**. Today, a modern technology called "trigeneration" enables the use of a heat pump for heating in winter and for cooling in summer (see Chapter – 4.3.3. Trigeneration).

2.4 | Clean coal technologies

Traditional coal combustion on a grate is still the most common technology for smaller coal boilers. This is mainly used in industrial and local equipment for central heat supplies in the Czech Republic.

Today's boilers in steam turbine power plants use either pulverized (dry bottom) or fluidized bed combustion. These boilers produce steam that drive turbines for generating electricity.

The steam being produced by existing electrical boilers does not reach critical specifications. This means that the steam pressure reaches a maximum 18 MPa, and its temperature fluctuates between 540 and 580 °C. This allows for maximum clean energy efficiency[6] at a range of 32–35%. In order to increase the energy efficiency, decrease **airborne release contaminants** and achieve fuel savings, better systems called "clean coal technology" have been developed.

2.4.1 | Pulverized coal combustion with supercritical steam specifications

To achieve more efficient power units, boilers and power units (including turbines) that work with supercritical steam specifications have been constructed. Power units that use above critical specifications reach a steam pressure of 25–31.5 MPa and a steam temperature of 600–610 °C. This allows for clean energy efficiency ranging between 42 and 43%. Power units working with a pressure of 35 MPa and a steam temperature of 700 °C and able to achieve clean energy efficiency up to 50% are being developed. **As a result of increasing the thermal efficiency of power plants, a smaller amount of fuel is being used for producing the same amount of electricity, and airborne release contaminants have significantly decreased**.

A newly constructed unit at the Ledvice power plant with supercritical parameters will allow for clean efficiency between 42 and 43% (with gross efficiency of 47%), using steam pressure of 28 MPa and a temperature of 600–610 °C. A comparison of two "subcritical" units in operation at the Ledvice power plant with the "above critical" unit is shown in Table 4.

If the existing units in Czech power plants are modernised with the technology listed in Table 4 having supercritical parameters, **a significant contribution to environmental protection in the form of savings of emissions into the atmosphere** can be expected **compared to the use of the technology with subcritical parameters**.

6 energy efficiency – the ratio of energy included in the input fuel against the electrical output of a power plant as measured at the generator

TABLE 4 | **Comparing the specifications of subcritical units being used with the above critical unit being built at the Ledvice power plant [MW, %, $kg.MWh^{-1}$, $mg.m^{-3}$]**

Indicator	Existing sources	New source
Output (electrical) [MW]	2 x 110	660
Gross efficiency [%]	37	47
Coal consumption [$kg.MWh^{-1}$]	1 130	656
Specific emission of PM [$kg.MWh^{-1}$]	0.09	0.06
Specific emission of SO_2 [$kg.MWh^{-1}$]	5.01	0.41
Specific emission of NO_x [$kg.MWh^{-1}$]	2.11	0.55
Emission limit of PM [$mg.m^{-3}$]	100	20
Emission limit of SO_2 [$mg.m^{-3}$]	1 700	150
Emission limit of NO_x [$mg.m^{-3}$]	650	200

SOURCE | MoE

2.4.2 | Integrated gasification combined cycle

Power plants with an integrated gasification combined cycle are considered **the cleanest and the most effective methods for using coal**. IGCC systems can be optimised for various types of fuel, including coal, petroleum (oil), coke, biomass and communal waste. During the process of IGCC, appropriate fuel is transformed into gas with high hydrogen content. Then, the gas is used as fuel for combustion gas turbines. Today's energy efficiency of these power plants fluctuates between 40 and 45%. Future combustion turbine research and other expected improvements will increase this efficiency beyond 50%.

Comparison to previous types of pulverized coal power plants, these IGCC power plants are more expensive and still require additional study. **Their advantage, however, lies in their following strict ecological limits**.

2.5 | Technology for CO_2 capture and storage

Carbon capture and storage is a technology that **has a potential to achieve high reductions in the emissions of CO_2**. CCS can be applied anywhere that a large amount of CO_2 is created, but it is supposed to find its primary use in energy. Manufacturing resources equipped with CCS are identified as low-emission or even zero-emission energy sources. The purpose of CO_2 underground storage is to **restrict greenhouse gas emissions into the atmosphere and the possibility of eventual CO_2 use in the future**. However, CCS technologies have not yet been developed and verified on a scale necessary for mass use in energy. Support for the establishment of 10 to 12 full capacity CCS demonstration units in the EU, which should be put into operation by 2015, is one of purposes of the Action Plan for Energy of the European Council of March 2007.

The whole energy cycle with CCS technology consists of separating CO_2 from combustion products and gas being formed by the gasification of carbon fuel, then transporting separated CO_2 to a storing facility and finally taking the stored CO_2 to a suitable deep geologic formation. The European Commission assumes the expansion of these technologies after 2020. Power plants being built before this date will have to contemplate the later addition of this system.

Presently, ČEZ, a.s. is planning to **build facilities for CO_2 storage in two locations** in the Czech Republic. The first one is supposed to be in Ledvice, where the construction of a new unit is planned. The other is supposed to be in the Hodonín region. The costs of using this technology range from 25 to 60 EUR per tonne of CO_2. For industrial use, a price around 20 EUR per tonne of CO_2 would be acceptable.

2.6 | Nuclear energetics

One of the options to reduce the negative impacts of emissions on the Earth's climate is to use nuclear energy. **Nuclear power engineering does not practically produce any internationally reported greenhouse gases (CO_2) and as an alternative to coal sources it significantly contributes to reducing emissions**. For example, a 1000 MW nuclear power plant will decrease CO_2 emissions into the air by 960 tonnes of CO_2 per 1 GWh of electricity compared to a thermal plant of the same capacity. **In addition, it does not use primary sources that can be used for other purposes**, e.g. in chemistry or medicine.

The current state-of-the art nuclear power plant projects that have started in Finland and France use generation III+ reactors. After 2025, generation IV reactors that are subject to intense research now will be added. The Czech Republic participates in the development of generation IV reactors via the Nuclear Research Institute Řež which provides to the EU experimental facilities built from the EU Structural Funds. Generation IV reactors allow for uranium 238, which is non-fission under normal circumstances, to generate a fissionable material that is used in current reactors. This increases the fuel

efficiency enormously. In addition to the above uranium, these reactors can also used thorium as a fuel. Their side effects include extensive heat generation which can be used for hydrogen production.

The fuel cycle ending in nuclear power plants is subject to intense research; the Czech Republic contributes to it via the Nuclear Research Institute Řež. Currently, roughly 50% of nuclear waste can be reused after reprocessing. Generation III+ reactors will allow for 100% reprocessed fuel. This applies also to generation IV reactors. Undesirable nuclear waste becomes a strategic material of the future.

2.7 | Intelligent network development

Science and research are trying to answer the problems of energy being lost from the connection of large power plants to the high voltage transmission network after the transformation down to a lower voltage when energy is distributed to final consumers. The capacity of distribution networks was constructed from the view of expected consumption at the distribution network's end. Today, a number of small sources, producing energy mainly from RES, are being connected to the existing distribution networks. This cannot occur without adjusting the distribution networks to accommodate new generation capacities. **Connecting plants that produce energy from RES to existing distribution networks will be enabled through new "intelligent" technologies.** Intelligent networks are power and communication networks that **will enable the flow of electrical energy between suppliers and customers in order to optimise the generation process, consumption and "energy storage" and operate the transmission and distribution networks in real time.** They will interconnect decentralized sources and will control the operation of intelligent networks so that they will act as one "classical" more efficient generation unit that has no significant negative impacts on operating the entire system.

The Department of Telecommunication Engineering in the Faculty of Electrical Engineering of CTU in Prague is engaged in this research and development in the Czech Republic.

2.8 | Increasing energy efficiency and energy savings

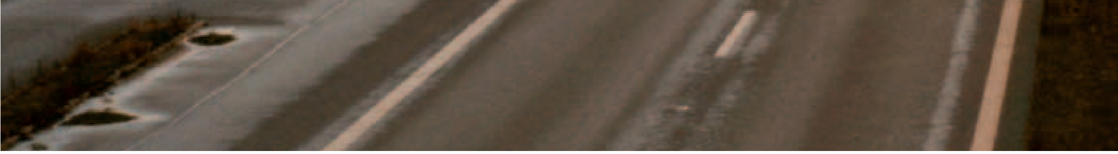
Energy savings also contribute to a sustainable development of power engineering. **In the Czech Republic, energy saving projects are supported from subsidy programmes of the** State Environmental Fund, the Ministry of Industry and Trade and the Ministry for Regional Development. In April 2009, a programme supporting renewable energy sources and energy savings in residential buildings was launched. This programme is financed from the sale of emission credits entitled **Green for Savings**. It is **the largest environmental subsidy programme designated to Czech households in the history**. Its aim is to support selected measures implemented in residential buildings by individuals and other entities that own residential buildings. The measures will both immediately reduce CO_2 emissions and start a long-term trend of sustainable construction. Thanks to the Green for Savings programme, Czech annual CO_2 emissions will be by more than million tonnes lower and dust particle emissions will decrease by 220 000 kg. Individual sub-programme are focused on external insulation of buildings, replacement of environmentally unfriendly heating with low-emission biomass sources and efficient heat pumps, installation of biomass sources and efficient heat pumps in new buildings, installation of solar and thermal collectors and development of passive houses.

Energy savings are also covered by Priority Axis 3 “Sustainable Use of Energy Sources” under the **Operational Programme Environment** that has supported investment into the environment with more than CZK 37 billion. The above funds also represent a major eco-innovation support in the Czech Republic.

Energy labelling represents an important incentive for energy savings products. The energy label provides customers with information about which product is more energy efficient. The development of **new fuels for cars** also represents a high potential in savings and lower greenhouse gas and pollutant emissions.

Environmentally Friendly Motor Transport


3



3 | Environmentally Friendly Motor Transport

Traffic is one of the main factors that **affects the quality of the environment, especially air. The largest offender in this field is road traffic. Its negative effects are mainly seen in greenhouse gas emissions, the emissions of suspension particles and the emissions of nitrogen oxide and volatile organic substances, which are the precursors of ground-level ozone.** The emissions of these substances are produced during fuel combustion and re-suspension[1]. The programme for supporting environmentally friendly technologies in the Czech Republic (see Chapter 1.2.3 Environmental technologies in the Czech Republic) considers **transportation a significant branch with extensive research in these technologies, e.g. increasing the efficiency of engines, research in hybrid engines, research in vehicles consuming fuels with high contents of organic components, research in tyres with low friction coefficient, etc.** In the Czech Republic, the development and use of these innovative technologies has is varied. Some have been already applied into mass production, whereas the remaining portion (especially hybrid engines) at a stage of increasing development.

The implementation of environmentally friendly technologies in transportation is helping to reduce CO emissions. These have been reduced by more than 30% since 1995. This is mainly the result of the more efficient combustion of fuels and catalytic systems. **The implementation of biofuels also contributes to reducing specific emissions of CO_2.** However, it is necessary to keep in mind in this context that road transport volumes and outputs have increased significantly since 1990 and future growth is anticipated. **Environmentally friendly technologies help to mitigate (emission of greenhouse emissions, PM) or even completely stabilise and gradually reduce (emissions of CO, NO_x, HC) the increasing burdens.**

Following is a well-organised outline of the development of significant eco-innovative technologies in transportation implemented in the Czech Republic and the potential of their use. If the potential of new technologies in transportation is not used, the stipulated limits for pollutants and noise limit values will be more frequently exceeded, which will threaten the health of the inhabitants, especially those in municipal agglomerations.

1 re-suspension – a process where particles formerly settled onto a surface are blown away by the air blowing above this surface layer

3.1 | Increasing the efficiency of combustion engines

Currently, there is **a tendency to reduce engine volume and increase its efficiency through supercharging by a turbo blower or compressor.** Systems with variable suction lengths, variable timing, valve lifts and different methods for recirculating exhaust fumes are used in the preparation of fuel-air blends. Fuel consumption is also reduced by decreasing friction losses in engines, by improving materials used for guide surfaces and by using high-quality lubricants. **Another benefit of these systems is a reduction in CO_2 emissions and engine fuel consumption.** The scope of their use depends on the philosophy of individual companies and prices of particular vehicles. Maximum usage of all existing and newly developed measures is necessary if all vehicles are to comply with agreed-upon emission standards.

TABLE 5 | **A comparison of fuel consumption and CO_2 emissions in new Škoda Octavias [kW, Nm, l, g.km^{-1}]**

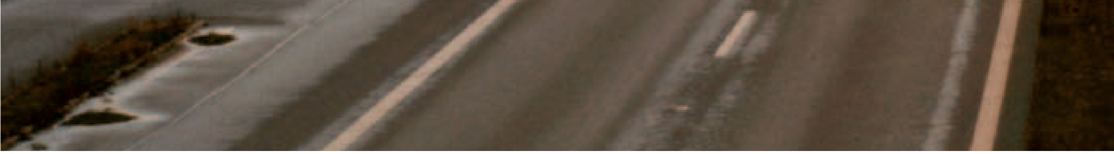
Engine	Fuel	Supercharging	Output [kW]	Angular momentum [Nm]	Combined consumption per 100 km [l]	Emissions CO_2 [g.km^{-1}]
1.6 MPI	petrol	no	75	148	7.4	176
1.4 TSI	petrol	turbo blower	90	200	6.6	154
1.9 TDI DPF	diesel	turbo blower	77	250	5.1	135
1.6 TDI DPF[2]	diesel	turbo blower	77	250	4.4	116

SOURCE | Škoda Auto a.s.

3.2 | Hybrid drives

The development of hybrid drives in the Czech Republic has advanced. This is mainly seen with the SOR brand of buses that will be equipped with a diesel engine, an electric drive and batteries. The manufacturer indicates **lower diesel oil consumption up to by 10 litres per 100 kilometres and lower CO_2 emissions by one-quarter** compared to the vehicles with a classical drive. Launching onto the market is anticipated by no later than 2011. In the Czech Republic, Bosch manufactures electric motors for parallel

2 1.6 TDI DPF – the model complies with CO_2 emission standards prescribing 120 grams per kilometre, which the EU plans to implement by 2012



hybrid drives that can be, thanks to their modular concept, adapted to the needs of car manufacturers. Their benefit is the **reduction of fuel consumption by up to 30% and therefore a marked decrease in CO_2 emissions – with spark-ignition engines by up to 25% and compression-ignition hybrid drives by up to 20%.** Due to their higher price compared to classical vehicles, the rate of use is relatively low in the Czech Republic. However, with a gradual increase in the number of competitors and production volumes, a reduction in the price of these technologies expansion can be anticipated.

3.3 | Vehicles consuming fuels with high contents of organic components

Škoda Auto a.s. has developed the Octavia Combi FlexFuel model that **can be fuelled by a high-percentage ethanol blend.** Materials that are more resistant to aggressive fuels are used for valve seats and the engine's fuel assembly. Due to ethanol's poor evaporation at low temperatures, the engine is equipped with a preheating unit. A control unit is adjusted to provide for the engine's smooth running when fuelled by arbitrary blends of E85 and petrol. **A vehicle fuelled by E85 complies with the Euro 4[3] and Euro 5[4]** limits. In the Czech Republic, flexi fuel vehicles are currently not sold. The reason is lacking infrastructure, missing tax allowances for E85 biofuels and insufficient legislative support.

All current Zetor engines are adapted for **consuming 100% ROME as well as more common blends of 30% ROME and 70% diesel oil**. Since 2007, there has been **development in fuel assemblies for pure vegetable oil.** Several functioning prototypes are in long-term testing stage.

TABLE 6 | **A comparison of emission factors of E85 mixed fuel and emission limits [g.km^{-1}]**

Personal vehicle – fuel	CO [g.km^{-1}]	NO_x [g.km^{-1}]	HC [g.km^{-1}]
Limit Euro 4 – petrol	1.000	0.080	0.100
Limit Euro 5 – petrol	1.000	0.060	0.100
Ford Focus Flexi Fuel – E85	0.145	0.012	0.026

SOURCE | Transport Research Centre

3 Euro 4 – emission standard for passenger vehicles valid since October 2005
4 Euro 5 – emission standard for passenger vehicles valid since October 2009

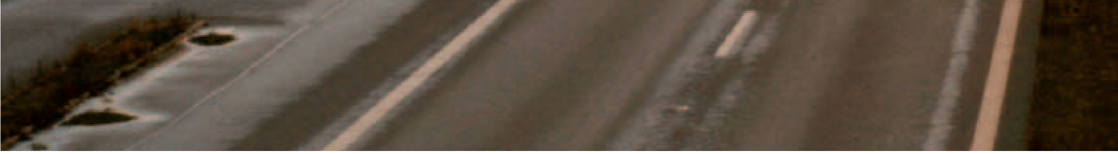
3.4 | CNG technology

Using CNG for vehicles means almost zero emissions of solid pollutants of PM and SO_2, CO_2 emissions lower by 10 to 15% compared to diesel engines and by 20 to 25% lower compared to petrol engines. CNG also reduces NO_x emissions by up to 60% compared to diesel engines. CNG engines contribute to the reduction of ground-level ozone[5] production. Another important property is **more silent running compared to classical engines**. CNG vehicles also have a longer travelling distance, lower operating costs and in the event of fire, there is virtually no risk of fuel tank explosion. Disadvantages include higher purchase costs and insufficient infrastructure.

In the Czech Republic, there are several manufacturers of CNG buses (Tedom s.r.o., SOR Libchavy spol. s r.o., Iveco Czech Republic, a. s., Ekobus a.s.), filling stations (Vítkovice Cylinders a.s., Bonett Bohemia, a.s., Adast Systems, a.s.) and a leading global manufacturer of seamless pressure containers (Vítkovice Cylinders a.s.). Compared to some other countries (Italy 432 900, Germany 68 700, Sweden 13 400, Switzerland 3 600 vehicles), their rate of use in the Czech Republic is low at the moment, only approximately 1 300 vehicles. The potential of using CNG technology in transportation is high and depends on legislation, the supply of vehicles and infrastructure. In the Czech Republic, there is legislative support in the form of a zero consumer tax and vehicle excise duty, subsidies for the purchase of public mass transport vehicles and public line traffic vehicles. However, infrastructure and the selection of CNG vehicles are insufficient.

The gas company RWE Transgas, a.s., buys Opel Combo CNG in order to renew its fleet. The CO_2 emissions in these vehicles are 132 g per kilometre, i.e. 15 g less than in vehicles the company was using before. At the annual load of 30 000 km, one vehicle produces 450 kg of CO_2 less. RWE is planning to get more than 100 CNG vehicles, saving at least 45 tonnes of CO_2 per year. Gas-fuelled company cars are also being implemented in VÍTKOVICE HOLDING, a.s. The fleet renewal will be completed in 2009 and as a result, all 200 current vehicles will be replaced with CNG cars.

5 ground-level ozone – a hazardous gas that is found just above the Earth's surface



3.5 | Hydrogen technologies

The first hydrogen-propelled bus in the Czech Republic is being developed at Škoda Electric a.s. in cooperation with foreign partners. Its concept is based on trolley buses produced by the same manufacturer. **The main power source is a fuel cell with secondary traction batteries and ultra-capacitors[6]**. Hydrogen is stored on the vehicle's roof in high-pressure containers. A control system allows for energy recovery in secondary resources and its reuse during acceleration. Board indicators will also include a presentation for passengers that will provide an easy-to-understand explanation of the function of individual components and at the same time will display the instant and overall savings of pollutant emissions. **The bus will be operated within the public mass transport system in Neratovice, where the first Czech hydrogen filling station will be put into operation for this purpose.** The main partner is Linde Gas a.s., which will provide fuel supplies in the future.

Use of hydrogen drives means almost zero gas emissions. For example, a twelve-cylinder engine in a BMW Hydrogen 7 vehicle, which allows for the combustion of hydrogen and petrol, produces only 5.2 grams of CO_2 per kilometre if fuelled by hydrogen.

The use of hydrogen drives currently has many technical problems starting with the need to liquidize hydrogen and keep it in liquid state. In the Czech Republic, the gradual expansion of the use of hydrogen drives is planned over the long-term. As with other alternative fuels, legislative support, the selection of vehicles and the establishment of sufficient infrastructure is necessary.

3.6 | Electric drives

The Czech Republic is one of the leading manufacturers of trolleybuses, trams and electric railway engines. Trolleybuses are manufactured by Škoda Electric a.s., SOR Libchavy spol. s r.o. and Dopravní podnik Ostrava a.s. The manufacturers of trams are Škoda Transportation a.s. and Inekon Group, a.s., whereas Pragoimex a.s., Krnovské opravny a strojírny s.r.o. and Pars nova a.s. deal with overall modernizations and renovations. A manufacturer of electric railway engines and suburban units is Škoda

6 ultra-capacitor – a condenser with a high capacity of many thousands of Farads that is capable of fast charging and discharging

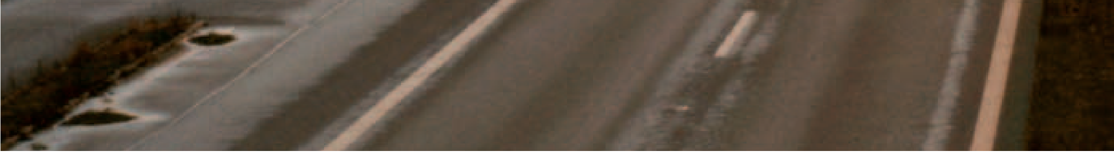
Transportation a.s., which also modernises the units of the Prague underground railway.

ČAS – SERVICE a.s., in cooperation with several organisations and research institutes, has developed and put into operation an **electric bus** in Znojmo that is based on Škoda's trolleybuses. The vehicle uses **nickel-cadmium storage batteries that allow it to travel from 110 to 130 km and are charged in garages. In morning traffic, the capacity of batteries goes down to approximately 50%. After twenty minutes of charging, they are charged at 80% and this allows the bus to run through the evening**.

The main benefit of the electric drive technology in transportation is zero emissions. At the same time, the likelihood of fluid release is minimized since they are used only in certain electric means of transport. The rate of usage of this technology in the Czech Republic is high with the exception of battery vehicles. **New types of storage batteries and ultra-capacitors (higher capacity, faster charging, lower weight and smaller dimensions) increase the potential of using electromobiles**. Legislative support currently exists only in the form of a vehicle excise duty. A vast supply of new passenger vehicles and Lorries (with the exception of light-weight utility vehicles and single-track vehicles) and charging stations is lacking. The supply of other electric means of transport and operating infrastructure is sufficient.

3.7 | Low-rolling resistance tyres

Tyres with low rolling resistance **contribute to the reduction in fuel consumption through the decrease in resistance during the tyres' motion** that mainly results from the deformation of wheels, tyres or the road. **The potential of CO_2 reduction with passenger vehicles that use low-rolling resistance tyres is estimated at approximately 3%.** Barum Continental spol. s r.o., a Czech tyre manufacturer, guarantees a reduction in fuel consumption and noise level thanks to a decrease in rolling resistance with current models compared to the previous generation of tyres. Compared to the previous Eco model range, **tyre rolling resistance has been successfully reduced by 20%**. This type of tyre is used in GreenLine models by Škoda Auto a.s.



3.8 | Saving power with roads

Research in energy consumption during road designing shows that roughly 16% of the costs of construction consist in energy costs and nearly 12% of this energy is consumed for road construction. **The construction of an asphalt road has many phases** that include procuring materials, material adjustments, the production of blends, transport, spreading and compacting. **Energy can be saved in each of these phases.** The two main procedures leading to energy consumption reduction during asphalt-covered road construction are the temperature required during production and application and the modification process.

A significant tendency that is being more and more often applied in the Czech Republic and responds to the need to reduce non-renewable resource consumption **is the recycling of road materials**. During recycling, which stared in Europe in the 1980's, energy savings are obtained from the reduction in transport (materials from quarries, blends, material removal). This reduces the need for fuels. **Various products can be recycled for use in roads, e.g. materials from old roads, excessive soil extracted during road construction and other materials** (industrial products, concrete from demolished buildings, scrapped tyres, glass, residues after home waste combusting, etc.).

3.9 | Technologies of traffic control in crisis situations

The national traffic data provision and control centre gathers and processes traffic data on accidents, closed roads, the practicability of roads, weather, etc. Traffic information is published on traffic data devices installed on highways and expressways, jointly broadcasted by the Czech Broadcasting Corporation through the RDS-TMC[7] service for navigation devices, published at http://www.dopravniinfo.cz and provided to other interested parties through a distribution interface. The highway network has **system of variable signs[8], a meteorological system,[9] traffic line control[10], systems**

7 RDS-TMC – a traffic news channel which is part of digital information broadcasted by radios in short waves
8 system of variable signs – a system of electronic panels which are able to show currently required traffic signs
9 meteorological system – a system of sensors for monitoring the temperature and air relative humidity, precipitations, wind speed and direction, etc.
10 line control – it serves for maintaining safe and fluent riding in a line track, the most frequently on a highway or expressway where the surroundings is unimportant for the traffic on relevant roads

for monitoring the characteristics of traffic flow and automatically detecting traffic jams on highways and alternate roads, cameras and other telematic systems[11]. They **contribute to traffic flow and a reduction in fuel consumption and subsequent reduction in emissions**. An expansion of the use of traffic data in personal vehicles depends on the development and expansion of board information systems and access to the Internet, as well as modern navigation devices supporting the RDS-TMC system.

11 telematic system –a traffic controlling and data providing system

Technologies Reducing Greenhouse Gas Emissions in Agriculture


4

4 | Technologies Reducing Greenhouse Gas Emissions in Agriculture

Agriculture has a landscape-shaping function and **primarily affects** three basic components of the environment: **soil, water and air**. **Agriculture mainly affects the environment through animal by-products from livestock husbandry,** which include barnyard manure, slurry, poultry excrement and litter, **as well as greenhouse gas emissions** such as nitrogen oxide and ammonia[1].

Between 1990 and 2000, thriftier use of nitrogen fertilizers, a reduction in livestock and observation of Good Agricultural Practice[2] principles brought about a reduction in greenhouse gas emissions produced in agriculture by 20% to the current level of 9% of all GHG produced in the EU. **The support of research and application of new technologies hopes to** further **reduce GHG production in agriculture.**

4.1 | Biotechnological additives

Biotechnological additives are substances based on enzymatic substances[3], bacteria, alginates[4], etc., **used to reduce emissions of ammonia and other burdening gases** from livestock husbandry, in barnyard manure dumps and the use of fertilizers.

The Research Institute for Agricultural Engineering **has examined the use of additives** containing extracts from yucca and seaweed, substances based on phytogenic[5] additives, a mix of growing oils, etc. The additives were tested from the perspective of **selected reduced GHG emissions and aerobic controlled high-speed composting.**

1 ammonia – a toxic, very harsh gas, causes damage to mucous membranes if inhaled
2 Good Agricultural Practice – generally known recommendations or requirements on how to farm in an environmentally friendly manner
3 enzymatic substances – complex proteins causing chemical reactions in an organism
4 alginates – extracts from seaweed
5 phytogenic – produced through the activity of plants

The effects of the application of biotechnological additives on the emissions of ammonia, carbon dioxide, nitrogen oxide and hydrogen sulphide were monitored. The experiment revealed that by **using biotechnological additives, a reduction in the emissions of all the aforementioned gases can occur and in case of ammonia, by an average of 30%.**

Immediately after the application of some additives, there was an increase in emissions followed by a reduction. The effect may be used in biogas production.

Selected biotechnological additives may be also applied in aerobic controlled high-speed composting. **The additives** stimulate thermophilic[6] bacteria into greater activity and propagation, which **accelerates the entire composting process. At the same time, they suppress emissions, especially of those of noxious smells**.

TABLE 7 | **Proven biotechnological additives that reduce ammonia emissions [%]**

Additive name	Area of use	NH_3 emission reduction
Amalgerol Classic	Additives in feed-water and feeding, for treating slurry and muck in poultry, pig and cattle breeding.	40
AROMEX SOLID Plus	Additives in pig feed.	48
BIOSTRONG 510	Additives for poultry feed.	48
SEKOL – JALKA	Additives for treating sties and slurry reservoirs in pig breeding.	32
MEX – Yucca DRY	Additives for adding in pig feed/poultry feed.	31/38

SOURCE | The Research Institute of Agricultural Engineering

Note: The table contains the most frequently used and the most efficient biotechnological additives. In the Czech Republic, SEKOL – JALKA is produced. It reduces ammonia emissions by up to 32%.

4.2 | Spraying technology

Spraying technology treats air in livestock stables, meat-processing facilities, in the leather and textile industries, sanitation companies, in waste water treatment plants, etc. Air in these facilities is **polluted by sulphur gases, ammonia and other malodorous substances.** Water with a special concentrate that decomposes air-borne

6 thermophilic – thriving at relatively high temperatures

ammonia and malodorous substances into salts and water is used to remove the pollutants. Fine mist is sprayed into the polluted air by a hydraulic or pneumatic sprayer and special nozzles.

In the Czech Republic, the technology has been tested at PROALIMEX spol. s r.o. in a farm in Kožichovice that deals with broiler breeding. **A 9.22% reduction in ammonia emissions was shown,** and **a biotechnological additive was simultaneously added to the feed. It reduced ammonia emissions and smells.**

4.3 | Technologies used for removing, storing and using excrement from livestock husbandry

4.3.1 | The technology of storing slurry in bags

The technology of storing slurry in bags is used at the Mišovice pig farm of Zea, a.s. The slurry in the breeding stalls is discharged by gravity flow from lower racks into buffer reservoirs. A pump and stirrer homogenises the contents of the reservoirs and pumps it into the main storage reservoir containing bags. These bags consist of a multilayer textile covered by plastic on both sides. The material is resistant to aggressive slurry and sunlight. The bags are filled from the top and pumped out from the bottom. **Thanks to the closed system of slurry pumping and storing, there is no leakage of ammonia emissions or smells into the environment.**

4.3.2 | Using separated slurry as plastic litter

Straw, the traditional litter material, is not currently available in most Czech farms. The reason is the more and more frequent division of agricultural production into livestock husbandry and plant growing. Therefore, various litter materials are used in current dairy cow box stabling.

A suitable medium is separated cattle slurry with approximately 60% solids specifically adjusted for littering box stables. **Littering in this manner increases the welfare of the stabled dairy cows, improves microclimatic conditions[7] in stables and**

7 microclimatic conditions – a complex actuation of multiple factors such as temperature, moisture and air flow rate, the chemical composition of air (a concentration especially of ammonia, carbon dioxide, methane, hydrogen sulphide), etc.

simultaneously reduces ammonia emissions by at least 30% compared to stabling with mattresses or straw.

In a plastic litter production line, solids are separated from raw cattle slurry that is freed of pathogenic microorganisms[8] during aerobic controlled high-speed composting. The composting process can be accelerated by adding suitable biotechnological addtitives that increase the temperature in stowing and improve the hygienic parameters of final products (see chapter 4.1 Biotechnological additives). Because plastic litter complies with the required characteristics of high-grade compost, any excess material may be used as a growing substrate.

Collective farm Krásná Hora nad Vltavou a. s. has been making use of plastic litter in dairy cow stables for five years. The farmers' coop uses plastic litter in its farm in Petrovice by employing aerobic high-speed composting in oblong heaps. Throughout this entire period of using plastic litter, microclimatic conditions have been periodically monitored in individual stables. It has been determined that annual ammonia emissions per dairy cow have decreased on average by 35% compared to stabling with mattresses or straw litter.

4.3.3 | Trigeneration

Controlled anaerobic fermentation[9] of biodegradable agricultural waste enables the use of energy bound in waste for producing biogas with a methane content of 50–75%. Biogas is used in common cogeneration units for producing thermal and electric energy (see Chapter 8.2.1 Biodegradable waste utilisation through the anaerobic digestion process). **Biogas may also be used for cooling through trigeneration, which is a combined production of electric energy, heat and cold**. A cogeneration unit is supplemented with an absorption thermal convertor that enables the conversion of thermal energy into cold. **The main benefit of absorption cooling is that thermal energy is used as output energy. It is cheaper than electric energy (mainly used in classical compressor cooling).** Trigeneration is especially

8 pathogenic organisms – disease-producing organisms
9 fermentation – a biotechnological process in which organic substances are gradually converted by the presence of microbial enzymes (ferments) to more elementary substances

applied during summer months when output heat from biogas stations is used in the air-conditioning of residential, administrative and technological buildings.

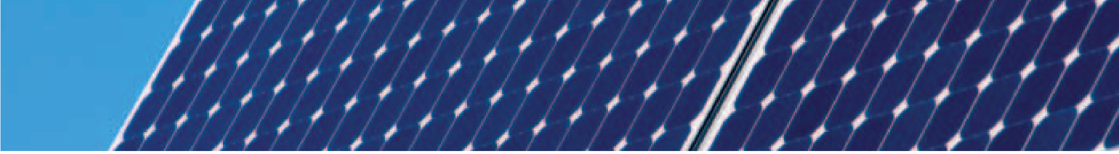
The implementation of trigeneration is planned at SP Poběžovice, a.s., a pig farm. Excessive thermal energy will be used in an absorption cooling unit that will be interconnected to a biogas station cogeneration unit that is already in use. The electric current produced by the station will be partially used in the facility and partially distributed to the public network. Waste heat will be used at the facility and for heating a fermenter[10]. The digestate[11] will be used to produce organic and inorganic fertilizers and distilled water. Part of the technology will also be used in a distilled water packaging line. At SP Poběžovice, installation of an all-season solar power plant is being planned, as is the construction of a waste water treatment plant – sludge produced in the WWTP will be used in the biogas station. The operator additionally plans to build greenhouses on adjacent parcels. Electric current and excessive heat produced in the biogas station will be used for heating and illuminating these greenhouses.

10 fermenter – a device providing ideal conditions for fermentation, such as the supply of required gasses, mixing, temperature, pH and oxidation

11 digestate – a residue after aerobic digestion, when registration conditions are met, it can be used as a fertilizer on agricultural land

Material Efficiency


5



5 | Material Efficiency

Climatic changes require an immediate response and identification of priorities for the future development of technology. In the Czech Republic, many research centres study the impacts of and possible solutions to climatic changes. There are also procedures known in the private sector that contribute to solving problems associated with climatic changes.

The development of photovoltaic systems is increasing in the Czech Republic. The third generation of PVS uses new low-cost technologies based on very efficient principles of converting solar radiation into electricity.

New technologies for preparing and producing **nano-fibres** and **research in the field of absorbents based on natural materials brought about a new patent** for catching pollutants.

The **research** dealing with the **impacts of climatic changes on forest eco-systems** in a model workplace in Moravskoslezské Beskydy **refines current information on the overall impact of climatic changes in various models**. Thanks to ample experimental equipment, innovative approaches and the complexity of performed experiments, the workplace is also part of an international network for monitoring the flow of materials and energies, FLUXNET.

5.1 | The development of photovoltaic technologies in the Czech Republic

Interest in converting solar energy into electricity has sharply increased in the Czech Republic. **Thanks to the implementation of the redemption prices system in the Czech Republic, the installed capacity grew from 0.9 MWp at the beginning of 2006 to 55 MWp at the end of 2008.** Chapter 2.2.4 Photovoltaic power plants, deals with power production by using PVS.

TABLE 8 | **Changes in installed capacity in the Czech Republic [MWp], 2000–2008**

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Off-grid systems I.	0.055	0.077	0.093	0.129	0.147	0.177	0.187	0.209	0.380
On-grid systems II.	0.017	0.047	0.062	0.160	0.216	0.292	0.682	5.152	54.294
Total	0.072	0.124	0.155	0.289	0.363	0.469	0.869	5.361	54.674

I. Off-grid systems – the systems that are not interconnected with electric distribution network
II. On-grid systems – the systems that are interconnected with a public network

SOURCE | CZREA

Photovoltaics are technologically versatile. The photovoltaic effect may be obtained through structures made of various semiconductor materials produced through a wide range of technological procedures. **In general, photovoltaics are divided into three basic generations**:

1st generation – these are **solar cells made of crystalline silica**; solar panels are made through the serial interconnection of individual solar cells,

2nd generation – these are **thin-film structures of semiconductor materials**, especially **based on amorphous and microcrystalline hydrogenated silica**; it also includes other semiconductor materials and structures (cadmium-telluride, copper-indium-gallium-selenide),

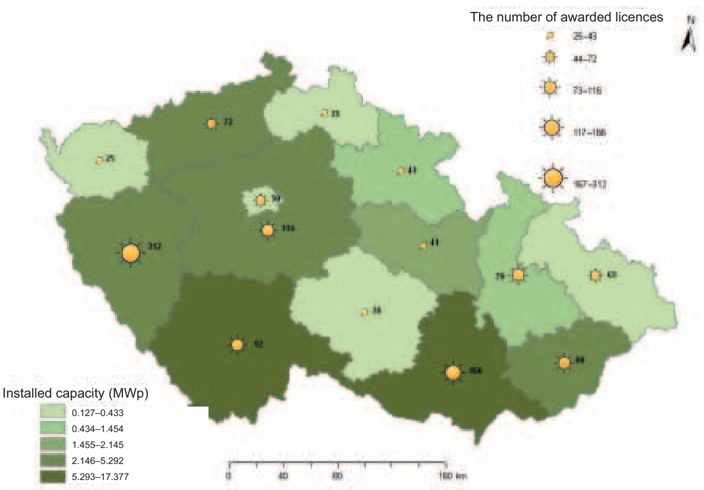
3rd generation – these are **new low-cost technologies** based on the highly efficient principles of converting solar energy into electricity.

A separate group includes organic and polymeric solar cells. Specific applications of solar cells include concentrator photovoltaic systems.

Czech regions show an overall growth in the installed capacity of PVS connected in the network (see Fig. 1).

Research and development in photovoltaics in the Czech Republic show a steadily rising trend. Research is not only concentrated in the workplaces of the Academy of Sciences of the Czech Republic and universities, but private companies are also devoting more and more time. Mutual relationships between individual research centres are supported by the exchange of knowledge and experience within regular Czech conferences on photovoltaics organised by CZREA.

FIG. 1 | **The installed capacity of PVS connected to the mains [MWp] and the number of licences granted by the Energy Regulatory Office in Czech regions as of 31 December 2008**



SOURCE | Energy Regulatory Office

5.1.1 | Technologies using crystalline silica

An abrupt growth in the use of photovoltaics throughout the world can be seen **by the amount of crystalline silica solar panels being produced. This shows this technology is still dominant.** The first crystalline silica solar cells in the Czech Republic were developed in the Czech Technical University laboratories in Prague and semi-industrially produced by Tesla Vrchlabí. During the end of the last decade, research and development was also conducted at the former Tesla Seznam in Rožnov pod Radhoštěm. Based on this successful development, Solartec s.r.o. was established in 1993. It deals with the research, development and production of solar cells. **Currently, research and development is aimed at those processing technologies that show great potential and have a special and highly efficient structure for solar cells. The properties of characteristic methods have been studied and optimised in order to analyze the materials and structures in crystalline silica solar cells** in

cooperation with the Faculty of Electrical Engineering and Information Technology of the Technical University in Brno, the Faculty of Electrical Engineering of CTU in Prague and the Institute of Scientific Instruments in Brno**.**

5.1.2 | Thin-film structures and semiconductor materials

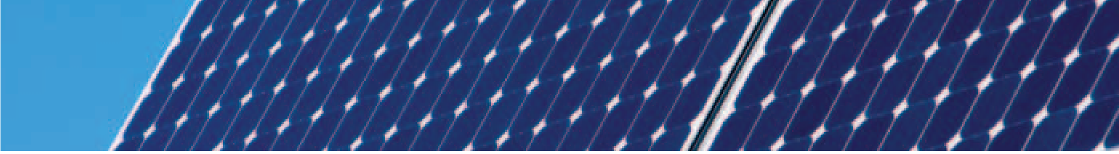
The most widely spread technology in this field is structures based on amorphous hydrogenated silica and microcrystalline silica. Long-term research and development is being conducted at the Institute of Physics of the Academy of Sciences on the Czech Republic in Prague**. The main aim of the research is to study the optoelectronic properties[1] of non-crystalline forms of silica and produce optic models of solar cell structures.** At the Institute, methods were implemented to analyse the magnitude of defects in amorphous and crystalline silica. Furthermore, a workplace has been established for producing thin films with the possibility of in-situ characterisation of topography as well as the morphology of layered surfaces.

The Research Centre for New Technologies at the University of West Bohemia in Plzeň also deals with thin films. **The research is aimed at depositing and characterising the physical properties of transparent conductive oxides, amorphous hydrogenated silica, microcrystalline silica and recrystallised polycrystalline silica.** Significant results have been obtained in the stabilisation of layers of amorphous hydrogenated silica against degradation as a consequence of the long-term actuation of light. This has been also verified in the structure of a photovoltaic cell.

Organic and polymeric[2] semi-conductor materials are the youngest technological branch that has a huge development potential because of their significantly lower costs. They are currently in the initial research phase. **Although it is the youngest branch of photovoltaics, the volume of research activities exceeds that of other branches in the Czech Republic.** Synthesising and studying properties of organic and polymeric materials for photovoltaics are the subject of the research being simultaneously conducted at several workplaces. The most significant in this field is the Institute of Macromolecular Chemistry of the Academy of Sciences of the Czech Republic in Prague where **complex research and development of new polymeric materials and systems is being conducted for the application in photovoltaics** including the

1 optoelectronic properties – the summary of optical and electronic properties of semiconductor materials reflecting their electronic structure (the density of electron states, valence and conduction band, the magnitude and power distribution of defects, spectral dependence of absorption coefficient, etc.)

2 polymeric semi-conductor materials – new types of organic semiconductors that replace costly cells that are mostly made of silica



design, preparation, characterisation of new materials and systems, studying of their properties and additional preparation and testing of polymeric photovoltaic cells.

5.1.3 | 3rd generation solar cells

The term 3rd generation solar cells includes many new principles that should make the greatest possible use of solar energy for conversion to electricity. Theoretical foundations have been laid for the new principles and many of them are currently undergoing their initial research phase. **The development of these technologies will bring the efficiency to over 50%.**

The Institute for Physics of the Academy of Sciences of the Czech Republic in Prague deals with the **research and development of structures of tandem solar cells with the combination of layers of amorphous and microcrystalline silica or silica nanoparticles[3].**

At the Research Centre for New Technologies at the University of West Bohemia in Plzeň, **research and development is taking place on photovoltaics based on silica with quantum structures[4] and for photonics[5] and micro-system technology based on aluminium nitride, zinc oxide and amorphous hydrogenated silica.**

A special group of photovoltaics is **concentrator systems**[6] that are mainly used in those fields with a prevalence of direct solar radiation. Although the Czech Republic is not one such area, attention is also given to their research and development. For domestic entities, this branch of photovoltaics mainly represents opportunities in export.

Thanks to a grant subsidy for implementing a demonstration photovoltaic system by the State Environmental Fund, small photovoltaic systems were installed in Czech schools and selected universities (300 installations) between 2000 and 2006 that created suitable conditions for research and development in photovoltaics. Therefore, **universities also deal with the topics of using photovoltaics in architecture and developing hybrid photovoltaic/photothermic solar collectors.**

3 nanoparticles – material elements (grains, fibres, etc.) below 200 nanometres
4 quantum structures – structures that make use of the effects of quantum physics – potential holes, quantum points
5 photonics – research and technology that deals with studying the properties and utilisation of photons
6 concentrator system – systems for using solar energy; their operation requires higher density solar radiation that is provided by using optical concentrators such as flat lenses and parabolic mirrors

5.2 | Czech Nanospider – a global technology for the production of nano-fibres for environmental applications

The Nanospider technology is unique in the world. **It is the only technology that enables the industrial production of fibres that are a thousand times thinner than human hair (nano-fibres)** and are able to produce millions of square meters of nano-fibrous materials every year.

The Nanospider technology was developed in cooperation with the Technical University in Liberec and Elmarco. It was awarded the Nano 50TM Prize granted by the prestigious magazine *Nanotech Briefs* (the official periodical of NASA) and was a nominee for two Index Awards that the INDEX 08 fair in Geneva. The technology is based on electrospinning[7] and protected by a patent and a trademark. The technology is used by several of the most significant international companies, especially in the USA and Asia.

Nano-fibres have a great potential in many applications and industrial production is the key to their use in environmental protection. The considerable porosity and high surface and volume coefficients of nano-fibres offer **extraordinary options for use in membrane technologies[8].** Molecules, macromolecules and cells may be connected by nano-fibres and such modified nano-fibres may be subsequently used in many areas from waste processing to chemical analysing and diagnostics through the use of biosensors.

For example, affinity membranes[9] are used in waste water treatment. This is because in certain cases it is impossible to completely eliminate certain types of contaminants by using traditional treatment methods either for inorganic pollutants such as cadmium, mercury and lead, or organic compounds – these all may be removed from waste water by using nano-fibre affinity membranes. **Nano-fibre technology considerably improves the efficiency of filtration capacity** for a given facility and **is able to remove fine, solid and liquid particles from the air. Thanks to its high efficiency and very low**

7 electrospinning – a method of spinning material from solutions or melts based on applying a direct current electric field
8 membrane technologies – methods and processes for separating solid particles and liquids using porous membranes or filters
9 affinity membranes – special membranes based on nano-fibres that can absorb selected pollutants and elements

pressure, it complies with the strictest requirements for many liquid filtration facilities. Nano-fibres may therefore help to resolve the global lack of drinking water, may help to make sea water desalinisation easier and more efficient.

Furthermore, nano-fibres may be used in producing energy from renewable resources. Nano-fibres can replace both classical silica cells and the new generation of cells with nano-composites[10]. They also enable operation in aggravated light conditions (no sunshine) and the use of mobile power sources (the combination of solar cells with batteries for nano-fibres).

5.3 | Absorption materials based on natural minerals

Natural materials that may be used as absorbents for water contaminants or waste gases **include minerals such as montmorillonite, bentonite, kaolinite, halloysite, etc. However, natural minerals are hydrophilic[11] and are unsuitable for absorbing organic pollutants.** They feature layered structures with a layer thickness of ca 1 nm. The space between individual layers, the interlayer, is filled with inorganic cations which compensate for the negative charge in inner layers of a mineral. **Replacing inorganic cations in interlayers by organic cations causes changes to the mineral's properties and therefore becomes organophilic[12] and enables the absorption of organic pollutants.** The properties of absorbents are given by organic cations used.

For clay minerals, minerals based on smectites are the most frequently used for these modifications to environmental technologies. For waste water treatment technologies, organically modified clays may be used separately as absorption materials for treating waste water contaminated by organic compounds, e.g. crude oil hydrocarbons, or in combination with active coal. They can form a part of the clay barriers and absorbents of organic substances in dumps.

Another suitable natural material seems to be vermiculite, whose use is currently being analysed at the University of Mining – the Technical University of Ostrava. The research is mainly aimed at preparing and testing organically modified vermiculite for absorption of organic substances from waste water and gases. Organically modified clay has been made from vermiculite mined in the Czech deposit of Letovice and efficiently absorbs organic substances found in waste water.

10 nano-composites – materials consisting of two or more different components where one of them is up to tens of nanometers; these are mostly nano-particles of active substances
11 hydrophilic – able to absorb water or be diluted in water
12 organophilic – able to bound organic substances or dilute in organic solvents

5.4 | Experience with the operation of an experimental centre of the Institute of Systems Biology and Ecology of the Academy of Sciences in Bílý Kříž

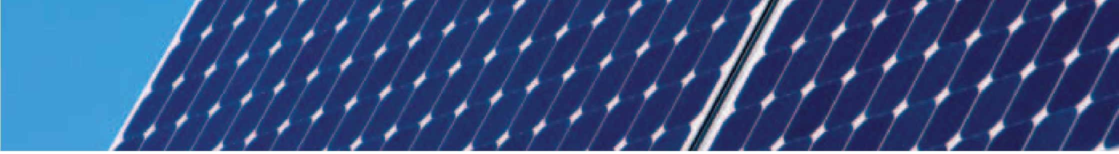
Complex ecophysiological research on the impact of climatic changes on eco-systems is being conducted at the experimental centre of the **Institute of Biology and Ecology Systems** of the AS CR, v. v. i. Bílý Kříž in Moravskoslezské Beskydy. As part of this research, the latest measuring technologies have been applied and specific new technologies have been developed. These include two **lamellar cultivation areas with an area of 1 are for long-term growing of mountain eco-systems in environments with enhanced concentrations of CO_2.** Plants are grown under common concentrations of CO_2 in the first cultivation area and under approximately double CO_2 concentrations in the second area. Another facility is a **cultivation facility for growing plants under enhanced intensities of ultraviolet radiation (UV-B).** Typical positive characteristics of plants grown in the atmosphere with increased concentrations of CO_2 compared to plants grown in atmospheres with natural CO_2 concentrations are accelerated photosynthesis (CO_2 consumption), increase in root system biomasses and increases in water utilisation efficiency.

Since the mid90s, the **application of eddy covariance technology** has also been developed at ISBE. It is a technology that **enables the measuring of material flows** (CO_2, H_2O and other greenhouse gases) **and energies** (apparent and latent heat) **between the adjacent atmospheric layer and a given eco-system.** Currently, this technology is being used in the Czech Republic for studying pine and beech woods, meadows, wetlands and agro-eco-systems. **A technological improvement is the simultaneous direct measuring of the flows of CO_2 from soil and xyloid parts of plants through automatic chamber systems.** This enables the very precise determination of the amount of carbon that a given eco-system is able to absorb from the atmosphere. Over the last years, **monitoring the flow of materials in forest eco-systems has expanded to include continuous measuring of ozone and calculating of stomatal conductivity[13].**

Another innovation in ecophysiological research is the interconnection of integral gasometric methods[14] with visual methods for leaves. For this purpose, fluorescence display cameras have been developed that map spatial heterogeneity of

13 stomatal conductivity – the rate of pore opening on the surface of leaves where exchange of CO_2 and H_2O (water vapours) takes place between the leaves and the atmosphere

14 gasometric methods – methods enabling the determination of exchange of gases (CO_2, H_2O, etc.) between a leaf or the entire eco-system and the surrounding atmosphere; on grounds of these measuring the rate of photosynthesis and stomatal conductivity is specified



the efficiency of solar energy use in photosynthesis. Ground analyses of CO_2 flows in plants are interconnected with the methods of long-distance Earth surveying, which enables expansion of the research to larger territorial units. At ISBE, **bioreactors have also been developed that enable growing biomass for the power industry with direct utilisation of waste CO_2, e.g. from heat power plants.**

The Bílý Kříž experimental centre is a member of the EUFAR project (European Fleet For Airborne Research) supported by the European Commission. The main objective of the project is to integrate methods, practices and experts from airborne research and make use of this integration for long-distance Earth surveying of the environment and other Earth sciences.

In 2007, ISBE became a cofounder of the ICOS (Integrated Carbon Observation System) research consortium financed by project of The Seventh Framework Programme and incorporated into the international research infrastructures ESFRI (European Strategy Forum on Research Infrastructures). The main project objective is the long-term monitoring (2007–2027) of global carbon cycle and the emission of greenhouse gases and predicting their future trends.

Sustainable Water Management

6

6 | Sustainable Water Management

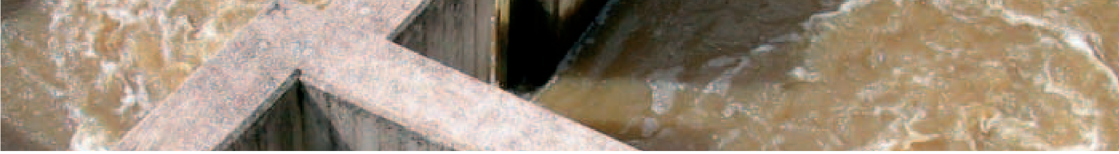
Water management is a set of activities that includes water utilisation, protection and economy. **Water is a basic component of the environment. Therefore, sustainable water management is one of the most important principles of nature and landscape protection**. The sustainable utilisation of water sources and the water economy is necessary for more than just the drinking water supply. A lack of water in general, and especially a lack of drinking water is a serious problem both in a European and a global context. In this respect, the Czech Republic has an exceptional position both in Europe and in the world. **The country's geographical location, geological structure and topography guarantee it will have sufficient sources of high-quality water.** Today, 92.3% of the inhabitants are supplied with drinking water and 83.4% of the inhabitants are connected to a sewer network in the Czech Republic. Many inhabitants of municipalities with less than 2 000 inhabitants are not connected to a sewer network. Their connection to a sewer system and subsequent waste water treatment has been too expensive so far. However, this is now being rectified or already has been rectified.

It is necessary to protect the water sources from the negative consequences of human activity. Today, protection of water bodies against **the effects connected with current** c**limatic changes** is also playing an important role**. It is necessary to manage water even better and to ensure the application of the state-of-the-art technologies in water management.**

The objective of sustainable water management is to ensure safe drinking water and total treatment of waste water from all towns, municipalities and diffuse sources where the waste water discharge threatens the state of the environment.

6.1 | Modern water treatment methods

The production of drinking water and water intended for food production is an important group of technologies in the water management area. It is based on having high-quality raw material. This equates to having high-quality groundwater or surface water (either from large rivers, lakes or reservoirs), which is gradually cleared of impurities by coarse screens and through sedimentation. Subsequently it is cleared of dissolved and very fine undissolved pollutants through chemical precipitation



(by means of coagulants[1]) under slow stirring (water clarification[2]) and subsequent filtration. Finally, it is cleared of germs through disinfection and safe drinking water results.

The necessity to remove substances that pass through the chemical clarification unaffected (especially nitrates brought into natural waters from large-scale agricultural production) requires continuous modernisation of water treatment methods. This mainly includes the **development of new coagulants that are friendlier to nature and to humans for water treatment through clarification, and the development of a more efficient and friendlier disinfection method**. The consequences related to global climate changes require support for **innovations in water management that will enable the provision of drinking water from those sources that were originally less convenient** (because of lack of ground water and of surface water). In addition, **they will enable the resolution of problems that arise due to the long-term storage and transport of treated and pre-treated water.**

Research of new coagulants and verification of safe common coagulants is ongoing and its results are being implemented in practice. In addition to classical water treatment procedures, other water treatment methods are being developed, applied and used in the Czech Republic:

- **thermal treatment (distillation)** – liquids with different boiling points are separated from each other by distillation,
- **reverse osmosis** – this is pressure filtration through a special membrane adapted to capture specification,
- **denitrification** – the biochemical decomposition of nitrates all the way down to basic nitrogen is occurring under defined conditions by specific microorganisms,
- **disinfection by UV radiation** preventing the formation of undesirable chlorinated organic compounds through the use of chlorine,
- **ozonisation** – disinfection by using ozone preventing the formation of undesirable chlorinated organic compounds through the use of chlorine,
- **nanofiltration** – a process similar to reverse osmosis using a different type of membrane that captures all inorganic salts and large organic compounds,
- **microfiltration** – this is pressure filtration through microfilters with specific pore sizes under defined conditions that also captures bacteria.

1 coagulant – a substance creating an insoluble compound with its impurities dissolved in water
2 water clarification – a mechanical-chemical process where water is stirred slowly while doses of coagulants are added; supports the formation of flakes of the precipitated impurities

Because the drinking water shall supply people with necessary nutrients, the filtration procedures and water distillation are used only for a part of the water being treated, e.g. for demineralised water production by MEGA a.s. for the boiling plants of the Ostravar and Velké Březno breweries.

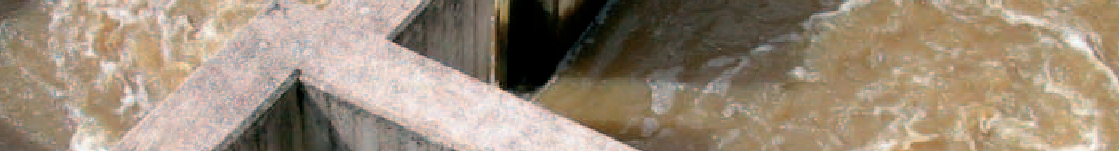
6.2 | Mine water and groundwater treatment

Inconsiderate interventions in landscape, extensive industrial production and a lack of environmental education were some of the reasons that some types of waste water were created (mostly in the old environmental burdens locations). After 1989, several methods to eliminate pollution from these waste waters were developed, tested and in the end successfully applied in the Czech Republic.

This special type waste water is contaminated groundwater that exists from production activities at industrial sites, unsecured landfills and the water draining or drawn from former mines. While mine water is usually polluted only with excessive quantities of dissolved inorganic salts[3] (without shares of especially dangerous pollutants), polluted groundwater mostly contains specific contaminants (heavy metals, oil products, pesticides and herbicides both of organic and inorganic origin). **The specific type of pollution requires specific treatment technologies and specific methods of pollution identification**, the development of which is taking place in the Czech Republic at the Institute of Chemistry and Technology of Environmental Protection at Brno University of Technology.

In the past, groundwater sanitation occurred either in situ (at the original place), by repeated re-pumping with the contaminant's displacement and collection (de-aeration[4]) or as contact filtration[5] connected with the regeneration of the filtration material[6]. This is the manner by which the contaminated groundwater near civil and all military airports was cleaned. **Today, sanitation of this type of water is carried out either by means of reverse osmosis or using the cleansing effects of the grown microorganism monoculture.** The mentioned technologies were patented abroad but **within the framework of international projects. Czech research institutes also**

3 inorganic salts – substances dissolved in water that are of neither animal nor plant origin
4 de-aeration – a procedure where the solution is bubbled through with air, into which dissolved gasses gradually pass
5 contact filtration – filtration through material (e.g. activated carbon) that can absorb (bind on the surface) some substances from the solution
6 regeneration of the filtration material – the removal of substances captured on filtration material, e.g. by thermal processing, which enables its reuse



participated in their research, e.g. the Institute of Microbiology of the Academy of Sciences of the Czech Republic.

The biological treatment principle by microorganisms is described in later parts of the chapter. In those special cases discussed above, the microorganism culture is able to quickly dispose of the required substances. An example includes the derivatives of petroleum. For these specific microorganisms to always work in the culture, it is necessary to always cultivate them in an auxiliary device and to add them into the treatment process itself.

In addition to the general physical-chemical processes, such as waste water distillation and ultrafiltration processes[7] (including reverse osmosis), for the sanitation of underground waste waters and mine water, **using selective procedures according to the type of the substance to be removed** comes into question**.** This includes the **application of a specific microorganism culture (oil products, organic pesticides) and special chemical and physical processes (ion exchangers, precipitation and leaching under specific conditions) including classical de-aeration (of waters contaminated by radioactive gases).** In the Czech Republic, contaminated water from landfills no longer being operated in Pozďátky (DIAMO, a state enterprise) or water from the Časy oil product sludge bed of PARAMO, a.s. in Pardubice (SITA CZ a.s.) will be treated in this way. Procedures to identify inorganic and organic contaminants in the water are a part of this process. Today, the research of specific procedures enables us to determine the pollution concentration at levels well below those dangerous to the environment.

6.3 | The treatment of municipal and industrial waste waters

Biological treatment[8] of the waste water is the most common and the most widespread manner of municipal and industrial waste water treatment. The basic process in biological waste water treatment systems is the decomposition of organic substances in which various microbial associations exist. At the same time, **some other processes conditioned by specialised bacteria species may take place under suitable conditions**. This includes the oxidation of ammonia to nitrites and nitrates (nitrifications[9]) through nitrification bacteria.

7 ultrafiltration processes – pressure filtration through special membranes
8 biological treatment –a process in which the biochemical processes of microorganisms are used
9 nitrification – the process of ammonia oxidation (NH_3, or NH_4^+) to nitrates (NO_3^-), namely via nitrites (NO_2^-)

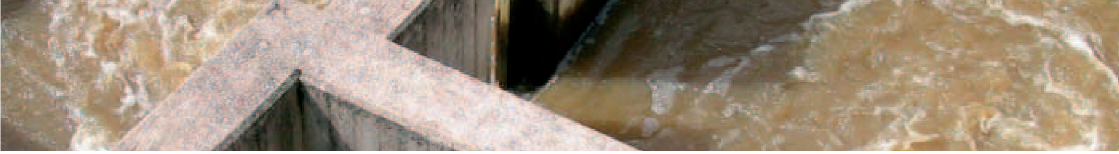
Biological waste water treatment may be divided into processes stimulating the natural conditions (earth filters, root treatment plants) or controlled processes taking place in reactors. The treatment methods in reactors may be further divided into processes with microorganisms in suspension (activation) and into processes with sessile microorganisms (sprinkling biological columns, rotary disc reactors). We can still divide waste water biological treatment into reactors according to whether the microorganisms ensuring the treatment process require the presence of oxygen (aerobic conditions) or whether they can work without the presence of oxygen (anaerobic conditions). Anaerobic waste water treatment methods are mainly used for industrial waste water with high organic substance concentrations, while aerobic treatment methods with the microorganisms in suspension are used in the majority of cases for municipal waste water treatment.

The basic principle of treatment is the formation of activated sludge[10] aerated in activation tanks. **The microorganisms in activated sludge make use of the individual components of the waste water for their life and growth, and thus they remove the polluting components from the waste water – they clean it.** A biological treatment plant consists of an aeration tank in which the process of waste water treatment with simultaneous activated sludge production takes place and a final settling tank where the treated waste water and the activated sludge are separated from each other by sedimentation. The treated waste water flows from the biological treatment plant into a recipient or it may be reused. The activated sludge thickened through sedimentation is returned back into the activation tank (returnable activated sludge). Because over course of treatment the activated sludge concentration in the tank increases (based on nutrients being constantly brought in with the waste water, the microorganisms grow and reproduce), it is necessary to regularly draw off a part of the activated sludge (the excessive activated sludge) from the system.

The issue of **removing specific substances in the water** has been gaining greater significance, **such as detergents, synthetic dyes, heavy metals and, last but not least, the remnants of pharmaceuticals, steroids and hormones.** These substances are not removed to a sufficient extent in common municipal waste water treatment plants. For this reason, biodegradation properties of other organisms are being searched for that would remove these special substances from waste water. Today, **experiments with some cultures of ligninolytic fungi[11], which have the capacity to**

10 activated sludge – a mixed bacterial culture possibly also containing other organisms such as fungi, moulds, yeast and protozoa, but also suspended and colloidal substances absorbed from water

11 ligninolytic fungi – known also as white rot fungi; the wood-destroying fungi decompose mainly the lignine components of wood; the white rot fungi prefer the dark lignine of the wood, and a light fibrous surface remains that consists mainly of cellulose fibres



decompose the mentioned specific substances, are being carried out in the Czech Republic. The main obstacle for their successful application in normal operation are completely different cultivation conditions, where, contrary to the activated sludge microorganisms, they work at pH levels lower than 5 and the temperatures higher than 26 °C. Activated sludge microorganisms work at pH levels of 6–7.

Municipal waste water mainly contains organic substances and compounds of nitrogen and phosphorus. Higher nitrogen and phosphorus concentrations in water leads to the eutrophication[12] of water with all accompanying negative effects (increased costs for treating this surface water into drinking water, hygienic problems for bathing, and fluctuations in the concentration of oxygen dissolved in the water, etc.). Also for this reason, the limits of total nitrogen and phosphorus at the discharge point from waste water treatment plants are constantly being reduced. Therefore, it was necessary to adapt WWTP technologies for nitrogen and phosphorus removal (the original biological treatment was designed mainly for organic substance removal).

It has been determined that the most important factor for the eutrophication of water is phosphorus concentration. During biological treatment, its removal with excessive sludge occurs because **it is possible to select processes that force microorganisms to accumulate more phosphorus in their bodies.** Based on today's legislative requirements on the discharge from WWTPs, this biological phosphorus removal is insufficient and not too efficient. **Today, phosphorus removal from waste water occurs through chemical precipitation**, namely by dosing iron and aluminium salts into the sludge and waste water mixture in the activation tank.

On the contrary, nitrogen removal occurs through new biological treatment methods, where the legal limits are achieved by **correct sequencing of the parts of a WWTP line with different concentrations of oxygen dissolved in water.** The way of sequencing oxic (with oxygen present) and anoxic zones (with lower oxygen concentrations) in a technological line may be generally described as follows: the waste water being brought in enters the anoxic zone, into which the thickened activated sludge is lead and the activation mixture from the end of the oxic zone with high nitrate concentrations. In the anoxic zone, the development of denitrification bacteria occurs that reduce the nitric nitrogen to nitrogen gas, and for this process they use the organic substances from the waste water being brought in. The activation mixture flows off into the oxic zone where the remaining organic pollution is removed and the ammonia nitrogen is oxidised into nitrates.

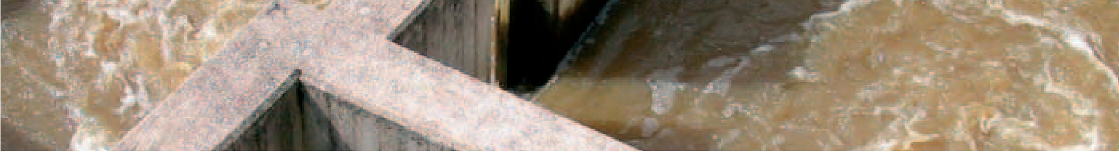
12 eutrophication – excessive growth of algae and cyanobacteria, the cause of which is a high concentration of nutrients in water; this mainly includes nitrogen and phosphorus compounds

The oxidation of ammonia nitrogen to nitric nitrogen in activation is ensured by nitrification bacteria. However, their share in activated sludge ranges only from 1 to 3%. Such low concentrations are given by the lower growth rate of nitrification bacteria compared to other bacteria. The most widespread manner of compensating for their low growth speed is increasing the sludge age[13], which, however, leads to reducing the bacteria activity and to the need of larger activation tanks. An alternative to increase the nitrification bacteria share in the activated sludge is the inclusion of **in situ nitrification bioaugmentation**, during which nitrification bacteria cultivation takes place in a detached part of the regeneration tank, into which a source is lead containing substances with nitrogen present, preferably the water from activated sludge dewatering. The grown nitrification bacteria are introduced back into the system in order to increase the nitrification bacteria concentration in the activation tank to increase the nitrification efficiency. This method was successfully applied in Prague's Central WWTP and in the Ústí nad Labem WWTP. By introducing this technology, a significant increase in the efficiency of nitrogen removal was reached. With the correct WWTP design with in situ nitrification bioaugmentation in place, the required activation tank sizes are reduced by as much as 40% and, at the same time, this brings an operating cost savings by as much as 10%.

6.4 | New methods of activated sludge separation

One of the essential phases of biological waste water treatment is the separation of activated sludge from treated waste water. Bad separation can lead to leakage of the activated sludge into the discharge, which significantly increases the concentrations of the discharge indicators and deteriorates the overall treatment. In the waste treatment practice, the classical final settling tanks are being more and more often replaced with **membrane filters**[14] that are either submerged directly into the activation tank or outside the activation tank, or they are located in a separate tank. Air is supplied into the system for biodegradation needs and for cleaning the membranes. The driving power of the treated water discharge is the difference of hydrostatic pressures[15] in front of and behind the membrane. The membrane modules eliminate the difficulties connected with activated sludge separation in the final settling tanks; **it is also possible to operate the system at much higher activated sludge concentrations**. Inasmuch as the membrane technologies usually range from microfiltration to ultrafiltration areas, **the disposal of all undissolved substances, bacteria and viruses occurs during**

13 sludge age – the average time that bacteria remain in the system
14 membrane filter – a filter made of plastic materials that serves as a sieve for separating the two phases
15 hydrostatic pressure – the pressure in a liquid that is caused by its weight

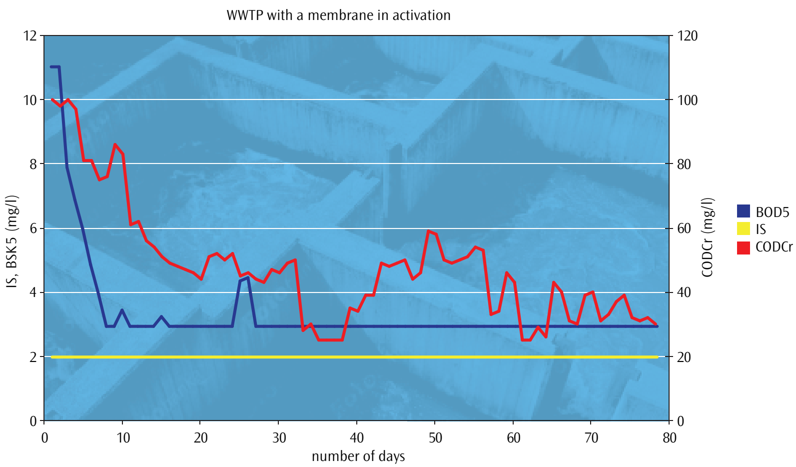


activated sludge separation. This enables treatment plants to reuse the treated waste water as supply water for recultivation, etc. A disadvantage of this technology is the gradual clogging of the membranes, which causes constant maintenance and a reduced service life of 7 to 10 years.

Inclusion of the membrane filters is especially advantageous when increasing WWTP capacity or modernising existing facilities. Where there is a lack of building space, in cases where it is necessary to eliminate seasonal deviations of waste water quality and quantity, in case of required high quality discharge from the treatment plant and when it is necessary to recirculate treated water back into operation recirculation back to the operation, this technology may be also used for all WWTP size categories.

In Graph 2, the discharge parameters are illustrative for a WWTP with a membrane placed in the activation with a size corresponding to the home WWTP category. Very low discharge concentrations are obvious from the Graph, mainly in the IS[16] (2 $mg.l^{-1}$) and BOD_5[17] (3 $mg.l^{-1}$) parameters. At the same time in this WWTP size category, the values of IS and BOD_5 about 10 $mg.l^{-1}$ and COD_{Cr}[18] about 70 $mg.l^{-1}$ are considered good results.

GRAPH 2 | **Discharge concentrations of a WWTP with a membrane in activation [$mg.l^{-1}$]**



SOURCE | Schönbauerová, Kučera, Jun (2009)

16 IS – insoluble substances in water
17 BOD_5 – biochemical oxygen demand for 5 days
18 COD_{Cr} – chemical oxygen demand determined by the ‘dichromate method’

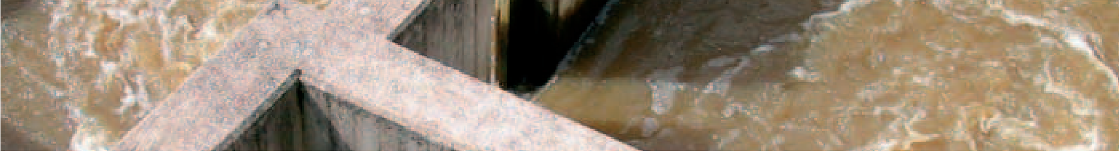
6.5 | Modern physical methods in the waste water treatment technology

Filtration is the most-used physical technology in waste water treatment; its use is possible on several levels. In the final waste water treatment, it is possible to use both common filtration on sand and mixed filters, as well as pressure filtration on microstrainers and micro to ultrafiltration on membranes. All the mentioned technologies **are used to remove the residual concentrations of undissolved substances in the discharge by capture on the filtration medium. Lowering the concentration of undissolved substances will also cause improved discharge concentrations of other pollution indicators** (total nitrogen, total phosphorus, COD_{Cr}). With this technology, it is always necessary to take account of the regeneration of the filter (the filtration bed) and of the disposal of the water used for this activity.

Sorption, as another method of final tertiary waste water treatment, works on the principle of accumulating (capture) the dissolved substances on the surface of the solid phase (adsorbent); the base material. Activated carbon is most often used as an adsorbent in the technology (powder or granulated). However, other sorption materials may be used, such as fly-ash, clinker, bentonites and organic polymer substances (styrene and divinylbenzene copolymers, acrylic acid esters). It is possible to intensify the filtration process by the adsorbent layer and by filtration bed’s surface. The sorption process is influenced by a number of factors including the size of adsorbent particles, the adsorbate concentration, temperature, pH, molecular weight and other specific properties of the substance being absorbed. Sorption is used **to remove carcinogenic and mutagenic substances, substances that are biologically degradable with difficulty or malodorous substances.** These mainly include residual concentrations of organic substances (chlorinated aromatic hydrocarbons, pesticides), heavy metals, free chlorine, etc. The regeneration and removal of exhausted sorbents may become a problematic issue of this technology.

The technology of electric-impulsion waste water treatment is a less-than-standard technology making use of the reaction of water to electric current**.** This technology is characterized by high efficiency **in reducing carbon pollution, eliminating nutrients and in removing undesirable substances, such as greases, degreasing agents, crude oil and oil products.** The principle of the operation is that strong electric and magnetic fields affect the continuous flow of polluted water. In this process, dissociation of the molecules[19] of the substances contained in the waste water occurs because of the action of the impulsion electromagnetic field. A consequence is

19 dissociation of molecules – dividing a compound’s molecules into separate ions



that macromolecules of these substances are formed. The undesirable substances are removed from the water as a flotation foam[20] and sludge leaving the process tank and the final settling tank. The system is similar to **electroflotation** where a coagulating agent is also added) for **treating (and pre-treating) water highly polluted from oils and greases.**

20 flotation foam – it is formed on the tank's surface of the gas bubbles (here arisen due to electric decomposition of water); it is the layer of foam in which the impurities attached to the bubbles are accumulated

Environmental Protection in Connection with Chemical Production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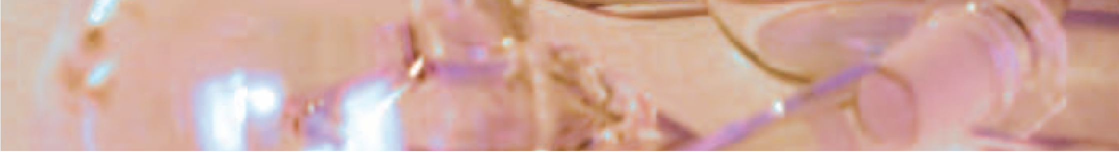


7 | Environmental Protection in Connection with Chemical Production

The chemical industry uses raw materials for energy, especially crude oil, gas and coal (to a smaller extent), **as both a power source and for production**. It accounts for 30% of the total global industrial consumption of power and raw materials. However, at the same time, **it provides a wide range of products that make it possible to produce power in environmentally friendly ways** (e.g. raw materials for the production of solar panels), **to store energy** (batteries) and to **save energy** (e.g. insulation materials and light-weight materials that save energy during their transport). Therefore, **chemical industry products often contribute to power savings and reducing emissions in other sectors.**

Intensive chemical research and innovations in industrial biotechnology[1], reaction processes[2] and material technologies **are mainly focused on improving the competitiveness, economic acceptability and accountability of the chemical industry. The impulse for implementing ecological innovations and economic technologies in the chemical industry is further enhanced by the effort to reduce the strong dependence of the raw material base of chemical products on fossil fuels and energy.** The potential of energy and raw material savings has not been completely realized; there are **still new research projects coming from the chemical industry that are aimed at environmental protection and sustainable development.**

At the end of 2005, The Czech Technology Platform for Sustainable Chemistry was established (SusChem ČR). It is part of The European Technology Platform for Sustainable Chemistry (SUSCHEM). The platform's basic objectives include increasing the competitiveness of the Czech chemical industry, forming a bridge between science, research and industry in the field of chemistry, promoting innovative activities and scientific-technical development in the chemical industry and involving the Czech Republic in the implementation of the main activities of SUSCHEM. In 2006, The Czech

1 industrial biotechnology – industrial technology using biological and biochemical procedures for its production

2 reaction processes – chemical processes where certain chemicals are transformed into other chemicals

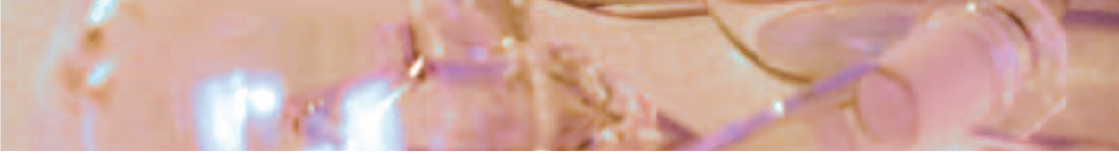
Technology Platform for Biofuels in Transport and the Chemical Industry was established. Its main aim is the sustainable production of biofuels in the Czech Republic.

In order to thoroughly survey the market with chemical agents and substances and to prevent unauthorized chemicals from entering the market, the EU adopted a new chemical policy (REACH[3]) in 2006. This was incorporated into Czech legislation by Act No. 356/2003 Coll., on chemical substances and chemical preparations. **The implementation of REACH will ensure that only those chemicals that have known properties and do not represent a threat to production plant personnel, product users and the environment will be produced and used in the EU by 2020.** The act on chemical agents and preparations also mandates the marking of chemical products.

7.1 | Aniline production using waste heat

Aniline is an organic compound used in the production of azo-dyes[4] and drugs. Aniline production is subject to a research conducted at the Institute of Chemical Technology in Prague in cooperation with BorsodChem MCHZ, s.r.o. The principle of aniline production is the catalytic reduction[5] of nitrobenzene[6] by using hydrogen through many columns for insulating pure aniline. There are several reduction systems that basically differ in the reactor and catalyst used. Adjustments to technology and subsequent increases in aniline production capacity to 150 kilotons per year together with many modifications aimed at reducing investment costs and improving power consumption made the **process self-sufficient in terms of heat consumption; in addition, it produces up to 1 ton of steam per 1 ton of aniline. This is used externally** in nitrobenzene production. **Thanks to better use of the power produced during the production process, no external power resources are required.** In 2003, the know-how and a licence for producing 150 kilotons of aniline per year were sold to Tosoh Corporation, a Japanese company. After the Japan unit was put into operation in 2005, the technology has been producing almost 10% of the world's consumption of aniline. The Czech Republic produces 5%, which is the largest amount within basic chemical products.

3 REACH – Regulation (EC) No 1907/2006 on the registration, evaluation, authorisation and restriction of chemicals and on the establishment of a European Chemicals Agency, REACH (Registration, Evaluation and Authorization of CHemicals)
4 azo-dyes – the most numerous and the most important group of organic dyes that includes all shades from yellow to black
5 catalytic reduction – chemical reactions with the use of a catalyst
6 nitrobenzene – an organic compound, the basic raw material for the production of aniline and azo-dyes

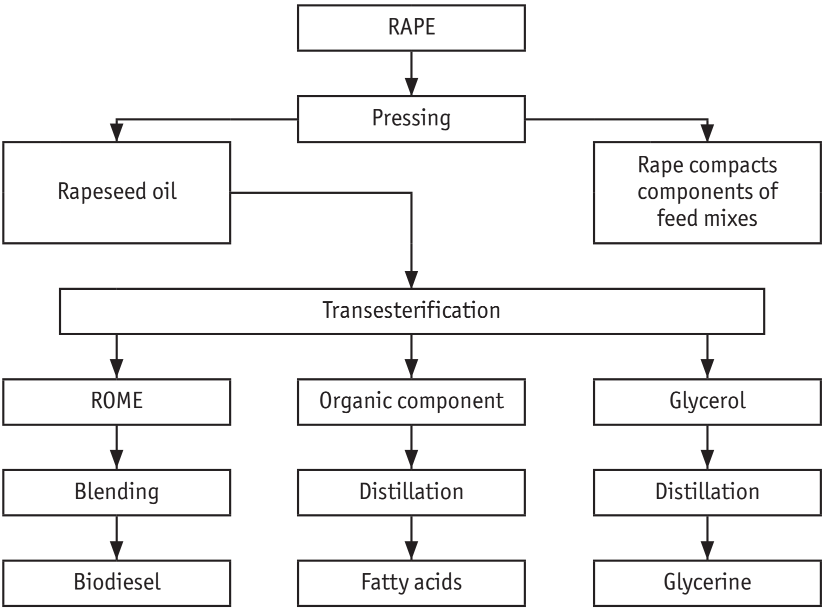


7.2 | Production of rapeseed oil methyl ester

Rapeseed oil methyl ester and bioethanol are 1st generation engine biofuels. Czech legislation requires adding biofuels to engine fuels. In 2009, 4.5% biodiesel shall be added to all diesel oil.

Rapeseed oil methyl ester (ROME) is 98% biologically degradable within 21 days, therefore improving the properties of blends with engine oil. By-products are additionally used in the chemical industry. The power balance of the entire ROME production cycle shows that **the overall power content of the products produced from input energy is six times or, as the case may be, three times higher** (according to the evaluation methodology used) **than the input energy.** The ROME and biodiesel production processes are outlined in Fig. 2.

FIG. 2 | **Technological scheme of biodiesel production**



SOURCE | *Biomasa* [online]

Legend of the terms:
Transesterification – chemical conversion of one acid ester to another ester
Distillation – a method of separating liquids based on various boiling points

The producers of ROME in the Czech Republic are e.g. SETUZA a.s., AGROPODNIK, a.s., Jihlava and KL-OIL s.r.o.

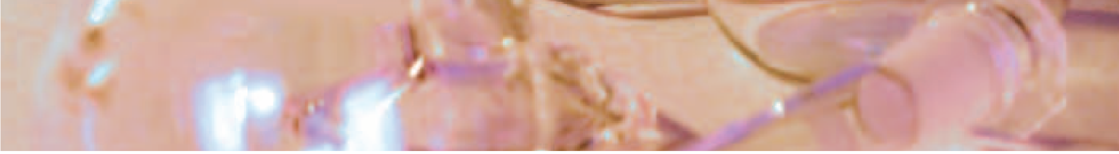
7.3 | The production of epichlorhydrine from renewable resources

Epichlorhydrine[7] is a key raw material for the production of epoxide resins[8]. It was formerly produced almost exclusively from propylene, a raw material obtained from crude oil. Presently, epichlorhydrine is produced in a combined manner. The synthesis of dichlorhydrine, the by-product, is still partly performed from propylene and partly from glycerine. Glycerine is a substance obtained from renewable vegetable resources.

The main benefits of this glycerine-based production technology are:

- high safety – the technology requires neither liquefied chlorine nor liquefied propylene,
- **lower environmental impacts –** lower production of all waste types, lower consumption of comparable raw materials,
- **low specific consumption of all types of energy,**
- high flexibility,
- **replacement of the key production raw material (propylene – from crude oil) with glycerine from a renewable resource**,
- competitiveness in terms of costs compared to other market representatives that uses several-fold higher production capacities.

7 epichlorhydrine – an organic compound that is used in the production of paper sizing agents and epoxide resins used for the production of liquid and powder coating compositions, the production of composites, in the building industry, electrical engineering and electronics
8 epoxide resins – a macromolecular organic substance used for the production of strong adhesives that adhere well to metals, glass, porcelain, leather, wood; epoxide resins also are used in the production of coating compositions and laminating agents; casting resins are mainly used in the electrical industry



Spolek pro chemickou a hutní výrobu, a.s., based in Ústí nad Labem (Spolchemie) implemented a unique technology developed by its own specialists. The technology consists of epichlorhydrine production from a renewable raw material resource (one of the by-products of biofuel production – glycerine). Spolchemie began trial operation of a new production unit at the beginning of 2007. After two years of operation, all the production line's design parameters have been fulfilled. The technology is protected by a patent in which many international producers are very interested. A unit based on Spolchemie's know-how is about to be constructed abroad.

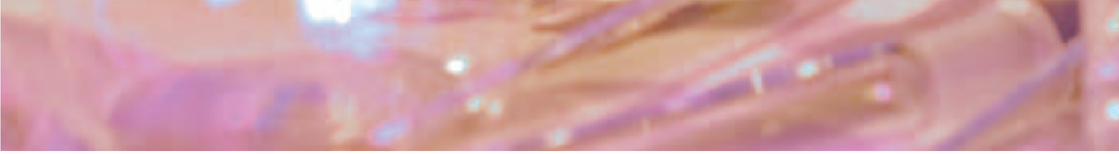
7.4 | Chemical products safe for streams

All products that could cause water pollution are tested for biodegradability and toxicity for water organisms. Chemical substances that are not biodegradable or are toxic for water organisms cannot be contained in such products.

In larger towns and villages, detergents are lead into waste water treatment plants to be biologically treated. However, in smaller villages, they are often discharged directly into streams (through septic tanks or home treatment plants that might not fully treat the water). Therefore, there is **an obligation** in the Czech Republic **that all detergent ingredients shall be tested for biodegradability.**

Water contains calcium and magnesium salts that affect the washing process and cause water hardness. Therefore, detergents shall contain ingredients that lead to water softening. To suppress the effect of calcium and magnesium salts, phosphorus compounds were formerly added to detergents. However, higher amounts of phosphates cause water eutrophication, which is a process of enriching water with nutrients, especially nitrogen and phosphorus. Excessive amounts of nutrients support the growth of phytoplankton, which can cause problems for some people who swim in water with higher phytoplankton concentrations. Water bloom further aggravates treating both potable and industrial water and may cause oxygen reduction in water and the subsequent death of organisms (fish, mussels). **Therefore, phosphates are now being replaced in detergents by molecular sieves[9] (zeolites).** These are substances that

9 molecular sieves – crystalline microporous materials able to bind calcium and magnesium salts



can bind calcium and magnesium salts. If discharged into streams, they enter into sediments and are harmless on the environment. The production of phosphate-free detergents is a contribution of chemistry to environmental protection.

Effective Waste Management

8

8 | Effective Waste Management

Waste is not only an epiphenomenon of the non-efficient treatment of non-renewable natural resources, but it is also a resource of raw materials and energies of increasing importance. Waste disposal and incomplete combustion of waste represent a **pollution source for soil, water and air by hazardous substances** (toxic metals and persistent organic pollutants, etc.).

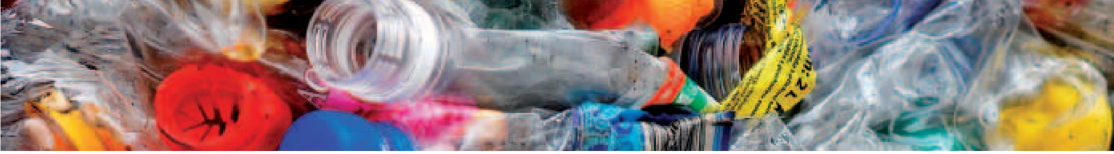
Waste management is a modern cross-technology field. It concerns both production and consumption and includes raw material extraction and processing, manufacturing and product consumption. It focuses on minimalisation waste production, efficient material and energy conversion of waste, and deals with waste treatment and disposal. The hierarchy of waste disposal is provided in Act No. 185/2001 Coll. on waste.

Minimalisation waste production and increasing the recycling rate is limited by economic potential and require not only new economic incentives, but mainly changes in the behaviour of producers and consumers. The need for reducing environmental burdens and the abatement supply of primary raw materials make it essential to **recover reusable materials from waste**. That is why there is relatively fast growth in the number and capacity of recycling facilities in the Czech Republic. **Most eco-innovative technologies in waste management regard waste as a raw material**. Technologies aimed at extraction selected materials from waste, technologies for recovering precious substances (such as precious metals) and technologies for processing biodegradable waste all contribute to the material utilisation of waste.

8.1 | The material utilisation of waste

8.1.1 | Recycling of cooling systems

In the Czech Republic, PRAKTIK LIBEREC, s.r.o. deals with the recycling of cooling systems and removal of Freon from cooling equipment. It is a **safe processing technology for end of life cooling systems** such as refrigerators and air-conditioning units from buildings and cars. In all these appliances, CFC is used as a refrigerant. CFCs, if released into the atmosphere, harm the Earth's ozone layer, which causes the penetration of an increased amount of UV-B radiation on the Earth's surface.



Equipment containing CFC is processed in two stages. In the first stage, CFCs are vacuumed off insulation and cooling circuits in a mixture with oil into a low-temperature condensing unit and then separated through thermal degasification[1] (both components are separated). CFCs are further pumped into pressurised containers and forwarded for disposal. In the second phase, insulation is crushed in vacuum. Materials obtained by adjusting electrical equipment are sent out for further use.

8.1.2 | Plasma technology in electric waste processing

One of the latest technologies for processing electronic waste is a plasma melting technology. In the Czech Republic, this technology is possessed by SAFINA, a.s, which has developed a unique process called PlasmaEnvi®. The process was designed specifically for processing industrial catalytic converters with the main emphasis on those containing precious metals. **Low-purity materials from scrapped electrical equipment are processed** through **plasma melting. These metals are mainly non-ferrous metals containing copper and precious metals**. Outputs of the technology are copper bars containing precious metals (gold, silver, palladium, platinum), i.e. predominantly non-ferrous metals containing copper and precious metals. In a plasma smelter, the aforementioned materials are re-melted and the obtained metals are then re-used. All pre-treated waste gases are combusted. Therefore, **valuable raw materials are obtained from waste while environmental burdens caused by emissions are minimised.** More extensive utilisation of the technology is anticipated in the future. There is no other low-purity waste processing technology in the Czech Republic.

8.1.3 | The recycling of plastics

In the Czech Republic, the recycling of plastics is performed either from mixed plastics or sorted plastics, e.g. PET[2] bottles, waste from the manufacture of plastics, etc.

Mixed plastic waste recycling is performed by Transform a.s. in Lázně Bohdaneč. They treat sorted plastics from communal waste. The waste is crushed, ground or in the case of film, agglomerated[3] and mixed in suitable proportions to make a product of required properties. The pre-treated mixture is then used to produce glass blocks,

1 thermal degasification – the process of heating a liquid and the gases bound in the liquid are released
2 PET – polyethylenterephthalate
3 agglomeration – thermal processing by sintering films in granules

flowerbed pavements, fence planks, cable gutters of various dimensions, transport pallets, boards, planks and various bar profiles.

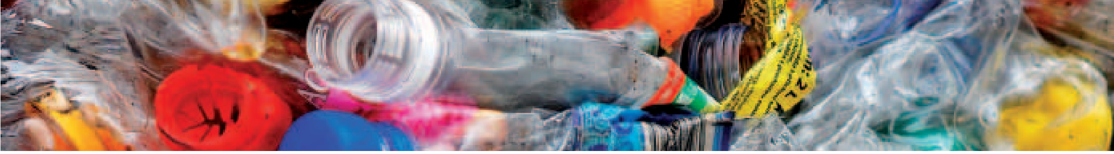
These **products are resistant to weather, have good mechanical properties, are not moisture-absorbent, are chemically inert, are lightweight and are fully recyclable**. In the Czech Republic, the production of polyester grain fibres obtained through the processing of PET waste is performed by SILON s.r.o. in Planá nad Lužnicí. After the initial treatment, PET waste is partly melted and after the desired properties are achieved, it is jet-injected into a conditioning shaft where the material cools down. The next steps depend primarily on the requirements for the final product (polyester staple, PET strap, PET film, etc.). During the manufacture of polyester fibres (TESIL® polyester fibre), known especially for the production of clothing, the fibres are further stretched to a thickness suitable for use in the textile industry. **In 2008, TESIL® polyester fibre was awarded the European Union eco-label** and the Environmentally Friendly Product label for textiles. Eco-labelling is a voluntary instrument for environmental protection. **Eco-labelled products are not only more environmentally friendly through all stages of their life, but are also healthier for consumers.**

8.1.4 | The recycling of selected waste

For the purpose of waste material utilisation, the following procedures are also used – crushing, sorting and grinding.

An example of using those procedures is the **recycling of scrapped tyres**. Through tyre recycling, new certified products are obtained that are suitable for anti-vibration plates, rubber tiles, etc. In the Czech Republic, many companies belong to the Czech Association for the Recycling of Tyres.

Another example of using these technologies is the **recycling of building waste** by crushing and subsequent sorting. Construction and demolition waste represents a significant portion of waste produced in the EU and in the Czech Republic; more than 25%. The quality of the recyclate depends on the grinding technology used for processing building waste. The same applies to asphalt-concrete recycled during reconstruction of roads. In the Czech Republic, the Association for the Development of Building Materials Recycling connects persons and organizations dealing with the issues of construction waste processing.



The interconnection of waste processing with subsequent utilisation of raw materials from waste in a treatment plant is occurring at Kovohutě Příbram nástupnická, a.s., which deals with the purchase and recycling of electrical waste, discarded electrical appliances, waste containing lead, lead-acid car batteries, waste containing precious metals and waste from scrapped vehicles. Subsequently, products for construction, engineering, healthcare, the chemical industry, electrical engineering, etc. are produced from recycled substances.

The advantage of recycling waste where the manufacture of acquired materials occurs lies in the elimination of traffic burdens when transporting waste to the recycling point and then from the recycling point to the processor of the obtained raw materials.

8.2 | Technologies for utilizing biologically degradable waste

In recent years, the effort to reduce disposing biodegradable waste into landfills has resulted in the development of technologies for processing municipal BDW as well as waste from agriculture, the food industry and forestry. The purpose of using these technologies is to produce a product that is re-useable (e.g., biofuels, compost and fertilizers).

8.2.1 | Biodegradable waste utilisation through the anaerobic digestion process

The principle of this technology is the **controlled conversion of biodegradable substances with high carbon content into methane and carbon dioxide.** The entire process takes place without air so that acid-forming and methane-forming bacteria can affect the input waste. The outputs of the technology are biogas and digestate[4]. **Biogas production is the main reason for using anaerobic digestion technology for BDW treatment. Biogas is used to produce electricity and thermal energy in biogas**

4 digestate – a solid or liquid residue found after anaerobic digestion; if it complies with certain requirements, it can be used as an agricultural fertilizer

station cogeneration units[5]. Waste treatment also takes place in the biogas stations. In the Czech Republic, the input in the facilities is mainly BDW from agricultural production, particularly manure, dung and suds, sludge from WWTPs, biodegradable household waste and waste from catering facilities.

The environmental benefits of biogas stations are mainly the outputs from the facility. If all technological processes and the quality of input waste are observed, any facility using this technology is in fact a **facility that uses waste for the production of materials and energy**. A large expansion of biogas stations is anticipated in the future as a means of treating biodegradable communal waste.

8.2.2 | Biodegradable waste utilisation through anaerobic fermentation

One of the devices treating BDW is the EWA aerobic fermentor of AGRO-EKO spol. s.r.o. in which **controlled thermophilic aerobic fermentation (composting) of a mixture of BDW and biomass from agriculture and forestry occurs**. In the mixture, the metabolic processes of the bacteria present in the bio-waste are activated by aeration and shovelling. This leads to the initiation and intensification of thermophilic aerobic fermentation. The subsequent increase in temperature cleans the mixture, i.e. eliminates present viruses, bacteria and molds to permissible levels. At the end of the process, waste humidity is reduced to a desired level through drying. The resulting product is a biofuel suitable for combustion in units that regularly combust biomass or low quality coal.

The system has low energy consumption since it is supplied by the energy produced from the recovery of the produced heat. The process is fast (about 4 days) and the final product has a wide range of possible applications.

8.3 | Waste processing through pyrolysis

The technology of pyrolysis processing organic waste in the Czech Republic is rapidly developing. It is a process of decomposing organic matter under the simultaneous actuation of heat without air, also called thermolysis. Heat leads to the degradation of complex organic compounds into simpler compounds. The product of pyrolysis is

5 cogeneration unit – a device on gas combustion engines that produces thermal energy and electricity during biogas combustion

a solid phase (based on coke), a liquid phase and a gas phase. **With this technology, all organic substances may be treated**, i.e. in terms of waste it applies to bio-waste and used tyres. The utilisation of all three product phases depends on the nature of the input raw material (waste). The **gas obtained after treatment can be used to produce electricity or thermal energy**. **The solid phase** in the output is a slag in which the pollutants are bound by strong bonds with zero extractability. Therefore, **it is suitable as an inert building material. For the pyrolysis of used tyres, the liquid phase in the output is diesel oil.**

The ENVICRACK cluster (the cluster of renewable resources) deals with technology development and putting its implementation into practice in the Czech Republic. It associates entities interested in the research and introduction of pyrolysis into practice.

8.4 | Flotation and reflotation

Flotation is a physical-chemical method of separation[6] that uses different wettability[7] of the surface of various minerals. The flotation technology appears in new applications such as the **decontamination of soils, the flotation of black printing ink during the processing of waste paper and the recycling of plastics** (plastics flotation makes use of their different densities; on an industrial scale it is used for the sorting plastic waste).

A specific flotation technology is reflotation, which is flotation carried out on raw materials that have already undergone the flotation treatment. **Reflotation is used to recover materials from waste in the treatment of coal that is kept in settling pits[8] and still contains a relatively high percentage of usable materials**. In the settling pits, it is not possible to ensure stable and quality raw materials extracted by hydraulic mining, because during sluicing (on the order of several years) the settling pits have changed the points of sludge inflow and the sludge properties are therefore very different.

6 separation – a process of treating raw materials or waste when useful components of a treated raw material are transformed into a concentrate and undesirable components

7 wettability – the adhesion of mineral surfaces to water; a physical-chemical property of solid particles of minerals important for flotation; wettability depends on the surface tension of a liquid and on the properties of the surface of a wetted material (composition, crystalline structure, etc.)

8 settling pit – an outdoor sedimentation basin for the settling and dewatering of solid compounds from WWTP waste, i.e. fine-grain waste from coal treatment

For the aforementioned reasons, the quality of sludge stored in settling pits needs to be examined before mining. Research on the coking properties of coal sludge blends revealed that the sludge extracted from outdoor settling pits can be used in limited quantities (approximately 10% of the reflotation product and 90% of coal) for the production of coal suitable for coking without affecting other elements such as ash or water content.

The reflotation technology is used in the Ostrava-Karviná District and **helps with the utilisation of settled coal sludge for the production of flotation concentrates. These are then used to prepare coal suitable for coking or for use as fuel for making energy.**

8.5 | Mineral biotechnologies

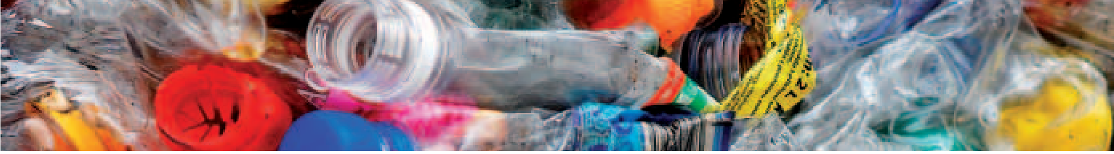
Progressive technologies in waste management include mineral biotechnologies. State-of-the-art knowledge in this field has moved from research activities to practical applications. The area of utilisation of biotechnologies in waste management is still being expanded to include new options.

Mineral biotechnologies include **technological processes that use micro-organisms or their metabolic products during the treatment or processing of waste materials.** Soil contaminated by crude oil products and pesticides can be decontaminated by **bio-degradation**. A bio-preparation of mixed bacterial cultures that help to accelerate the decomposition of contaminants in waste is applied on a prepared material. Bio-degradation can be performed either at the place of contamination (in-situ) or after the mining out or removal of contaminated media (ex-situ).

Bio-flotation has proven especially effective for the desulphurisation of fine-grain coal from which it is possible to float out pyrite.

Bio-flocculation is one of the available methods for processing very fine non-homogenous waste coal sludge. The principle of this process consists in the agglomeration of ultra-fine mineral components by the actuation of bio-flocculants[9]. The resulting flakes are separated from the suspension by sedimentation or filtration. Through bio-flocculation, a significant proportion of very fine grains can be removed, which has a positive effect on the speed, efficiency and reduction in the power intensity of the filtration and sedimentation processes.

9 bio-flocculants – microorganisms producing slimy substances which form a protective layer of cells



Bio-flotation flocculation is a process where bio-flocculants are applied on the raw materials intended for flotation in the first stage. This causes the agglomeration of useful components into flakes and these float out after the addition of flotation agents. It has been shown that the use of bio-flotation flocculation increases the mass yield of the products by up to 15% while maintaining the required quality of the concentrate with less than a 10% ash content.

Mineral biotechnologies are one of the main research topics at the Institute of Environmental Engineering, Mining and Geological Faculty, The University of Mining – Technical University in Ostrava. Long-term and traditional knowledge in the field of mineral resources treatment are used here.

Conclusion

The application of environmentally and eco-innovative technologies brought about the required positive effects of reducing industrial pollution and increasing environmental protection at the European level.

Environmentally friendly technologies can not only be applied in Europe, but can also serve as an export that fulfils two functions – these technologies represent an opportunity for better production and further innovation while helping to reduce environmental burdens where they are utilized. The transfer of know-how in the area of environmental technologies and eco-innovation, especially to Third World countries, is also viewed by the European Commission as an important environmental protection tool that requires increased attention these days.

The publication is an initial look into the issue of environmental technologies and eco-innovation in the Czech Republic. Concrete examples of successful development, production and the application of different technologies in practice prove that the Czech Republic is a country with a high potential of using advanced technologies in a number of industries and agricultural branches and that there is a high potential for their further application. Neither the definitions of sectors, nor the list of individual technologies are either final or closed. On the contrary, eco-innovation and environmental technologies can be applied in a wide range of situations in the Czech Republic.

This is also proved by the 8th edition of the European Innovation Scoreboard that was introduced in Brussels on 22 January 2009. The document compares the levels of innovative systems between EU member state policies and other selected countries.

The Czech Republic ranked 15th out of the EU27 and is among "moderate innovators". The Czech Republic's innovation efficiency is below the EU27 average, but the annual growth of the innovation index, used to measure innovation efficiency, is above the EU27 average.

List of Abbreviations

AS CR – Academy of Sciences of the Czech Republic
BAT – Best Available Techniques
BDW – biologically degradable waste
CCS – carbon capture and storage
CFC – chlorofluorocarbon
CNG – compressed natural gas
CTU – Czech Technical University
CZREA – Czech Renewable Energy Agency
EIA – Environmental Impact Assessment
EMAS – Environmental Management and Audit Scheme
ETAP – Environmental Technologies Action Plan
EU ETS – EU Emissions Trading Scheme
E85 – environmentally friendly biofuel
GDP – gross domestic product
GHC – greenhouse gas
GMO – genetically modified organisms
HC – hydrocarbons
HPP – hydro power plant
IGCC – Integrated Gasification Combined Cycle
ISBE – Institute of Biology and Ecology System
LCA – Life Cycle Assessment
MEYS – The Ministry of Education, Youth and Sports
MIT – The Ministry of Industry and Trade
MoA – The Ministry of Agriculture
MoE – The Ministry of the Environment
MT – The Ministry of Transport
NASA – The National Aeronautics and Space Administration
OECD –The Organisation for Economic Cooperation and Development
PM – particulate matters
PVPP – photovoltaic power plant
PVS – photovoltaic systems
R&D – research and development

RES – renewable energy sources
ROME – rape oil methyl ester
SEP – The State Environmental Policy of the Czech Republic
UNO – The United Nations Organization
VAT – Value Added Tax
v.v.i. – public research institution
WPP – wind power plant
WWTP – waste water treatment plant
6th EAP – The 6th Environmental Action Plan

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