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Table of Content

Preamble

It is with great pleasure that we present to you, for the fifth time, the Book of Abstracts for the Conference Energy Fuels Environment (EFE 2024). This conference addresses interdisciplinary topics related to energy, fuel production, energy policy, and the environment. The member states of the European Union are implementing the initiatives outlined in the European Green Deal, which requires collaboration among policymakers, entrepreneurs, the education sector, and the scientific community. These are precisely the goals of our conference.

Core topics include innovations in power and heat technologies, intelligent energy management systems, advances in nuclear energy, renewable energy technologies, and energy storage. The discussions will also cover clean fossil fuels, biofuels, waste fuel production, CO_2 utilization, and industrial catalysis. The conference will explore hydrogen production, storage, and applications, as well as the environmental impact of the energy sector, climate change, the circular economy, environmental protection, and emission standards.

In addition, the conference will address catalysis in alternative fuel production, the technological aspects and safety of nuclear energy, ecological transport, and the economic challenges of fuel and energy management. Materials for energy conversion and storage will also be discussed.

EFE 2024, held biennially, is co-organized by the AGH University of Krakow, the Faculty of Energy and Fuels, and the Cracow University of Technology, Faculty of Environmental and Power Engineering, Department of Power Engineering.

This year's edition also coincides with the 50th Anniversary of the Faculty of Energy and Fuels, which was established in 1974.

We hope that this collection of abstracts will provide valuable information and inspire fruitful discussions and collaborations.

Prof. Monika Motak
Dean of Faculty of Energy and Fuels

Hydrochars derived from agricultural digestate towards energy production

Joanna Mikusińska[1,*], **Klaudia Czerwińska**[1], **Zuzanna Prus**[1], **Monika Kuźnia**[1], **Małgorzata Wilk**[1]

Keywords: hydrochar, hydrothermal carbonization, digestate management, biofuels

ABSTRACT

Digestate is a high moisture by-product of biogas plant. It is a mixture of solid and wet fractions and its composition depends on feedstock used in the anaerobic digestion process [1]. During hydrothermal carbonization process (HTC) a feedstock is heated at the temperature range of 180-280 °C in an aquatic environment under autonomous pressure. As a result a hydrochar is obtained which is the solid product of the HTC process. It is a material with properties similar to lignite, which can be used as a fuel in industry [2].

In this study, hydrothermal carbonization process of agricultural digestate was performed at the temperature of 200 °C and 210 °C and 1 h, 1.5 h and 2 h of residence time. For each parameters, two processes (R1 and R2) were carried out to check the repeatability of the process. The fuel properties and combustion performance were evaluated by ultimate, proximate and thermal analyses. Then, carbonaceous properties were determined for hydrochar produced at the highest temperature and longest residence time. Table 1 shows the ultimate analysis, including moisture (M), ash and volatile matter (VM) of hydrochars performed at EU standards. The higher heating values (HHV) of raw digestate and hydrochars are presented in Figure 1.

Table 1. Fuel properties of hydrochars obtained of agricultural digestate

Name of sample	Time h	M %	Ash %	VM %	C %	H %	N %	S %	O %
HTC 200/1.0 R1	1	1.81	7.54	70.39	55.14	5.99	3.27	0.01	26.24
HTC 200/1.0 R2	1	1.84	8.52	68.46	54.61	5.91	3.13	0.01	25.98
HTC 200/1.5 R1	1.5	3.03	8.03	69.11	54.29	6.03	3.23	0.01	25.39
HTC 200/1.5 R2	1.5	1.47	7.23	70.43	55.57	5.97	3.21	0.01	26.54
HTC 200/2.0 R1	2	3.03	7.40	67.87	54.18	5.99	3.03	0.02	26.35
HTC 200/2.0 R2	2	2.22	7.44	68.36	55.57	6.00	3.16	0.02	25.59
HTC 210/1.0 R1	1	2.14	7.31	69.13	54.93	5.93	3.18	0.02	26.49
HTC 210/1.0 R2	1	1.29	7.62	68.74	55.65	6.03	3.10	0.01	26.30
HTC 210/1.5 R1	1.5	1.72	7.92	68.02	56.26	6.02	3.16	0.01	24.79
HTC 210/1.5 R2	1.5	1.87	8.52	65.68	55.69	6.02	3.19	0.02	24.70

HTC 210/2.0 R1	2	2.04	8.29	67.87	55.85	6.04	3.11	0.02	24.65
HTC 210/2.0 R2	2	1.92	8.76	67.44	56.41	6.00	3.20	0.02	23.69

Concluding, it can be stated that hydrochars obtained at 210 °C are characterized by a higher carbon content and higher HHV values than hydrochars produced in 200 °C. Therefore, higher temperatures of the HTC process are more suitable for obtaining better fuel properties of hydrochars.

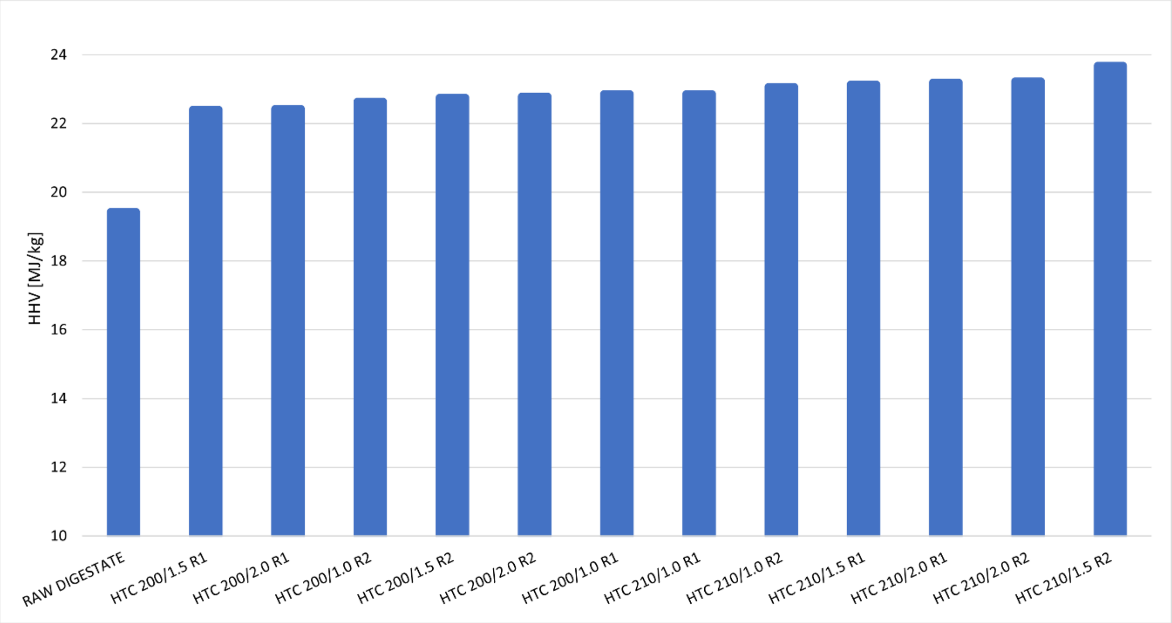

Figure 1. HHV values of raw digestate and hydrochars

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ENERGY FUELS ENVIRONMENT EFE2024
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Designing high-performance dual-phase hybrid electrodes for Solid Oxide Cells: the excellence of synergistic effects

Kun Zheng[1, 2]*, Jakub Lach[1], Michał Gogacz[1], Muhammad Bilal Hanif[3, 4], Amir Sultan[5], Jie Luo[6], Paweł Czaja[7], Fangjun Jin[8], Yihan Ling[8]

Keywords: heterostructure, in situ exsolution, dual-phase electrodes, composite, solid oxide cell

ABSTRACT

Solid Oxide Cells (SOCs) are among the most promising energy conversion and storage devices for the production and storage of electricity from traditional and renewable energy sources. When the consumption of electricity is low, the excess electrical energy can be stored in fuel/hydrogen yielded in the electrolysis mode of SOCs. In situations of higher electricity power demand, by the fuel cell mode of SOCs hydrogen is used to generate electrical power. However, high power outputs of SOCs are usually recorded at a high temperature range (around 800 °C). The high working temperature of SOCs drastically leads to a high operational cost, therefore limiting the choice range of device materials and the commercialization of SOCs. To boost the economic competitiveness, it is essential to lower the operational temperature to a range of $\leq$ 600 °C while still retaining a high-power performance. Therefore, the development of high-performance electrodes with enhanced electrocatalytic activities is indispensable for boosting the performance of SOCs. The design of dual-phase electrodes bringing a synergistic effect, significantly benefits the performance of SOCs, including the fabrication of heterostructured composite electrodes by mechanically milling or self-assembling techniques [1], *in situ* exsolution of secondary phase in the form of nanocatalysts [2]. Electrodes with unique dual-phase synergy substantially boost the electrochemical performance of SOCs [1-4].

In this study, various approaches to fabricate hybrid electrodes including *in situ* exsolution of secondary phase (nanocatalysts), mechanically milling to form composites and self-assembling dual phase materials have been employed and discussed, aiming to significantly improve the performance of SOCs. $Sr_2Fe_{2-x}W_xO_{6-\delta}$ perovskite electrodes with *in situ* exsolved metallic nanoparticles were designed. Excellent power outputs were recorded for the constructed symmetrical solid oxide cells based on developed hybrid electrodes, presenting the power of 679 mW cm^{-2} in hydrogen at 800 °C and 451 mW cm^{-2} in wet methane. Both mechanically milling and self-assembling techniques were applied for the fabricating $GdBa_{0.5}Sr_{0.5}CoCuO_{5+\delta}$-$Ce_{0.9}Gd_{0.1}O_{1.95}$ dual-phase electrodes, extensively

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promoting the electrochemical performance of the electrode at intermediate temperature range (≤ 700 °C). In addition, high-performance triple conducting $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$-$BaCe_{0.9-x}Mo_xY_{0.1}O_{3-\delta}$ composite has been manufactured utilizing a mechanical milling method, which significantly boosts the electrochemical performance of oxygen electrodes for SOFCs at 600°C, with an excellent stable power output of 418.7 mW cm^{-2} over 500 h measurements.

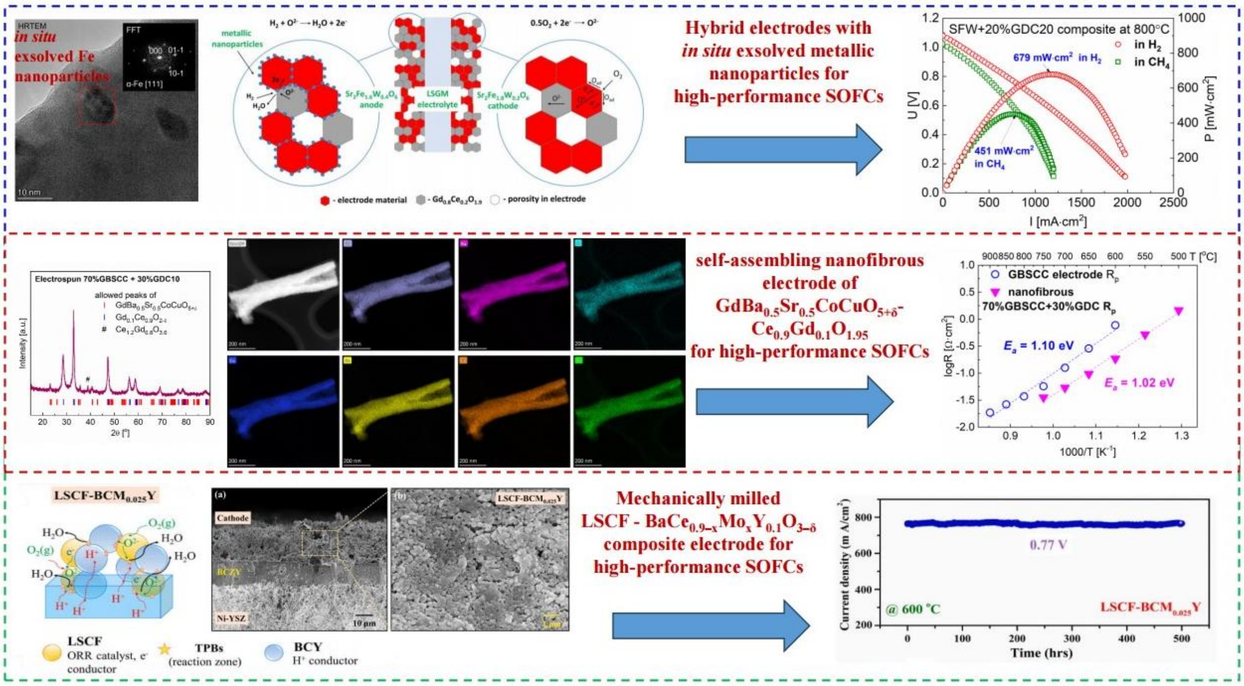

Figure 1. Designing dual-phase hybrid electrodes for high-performance Solid Oxide Cells.

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Acknowledgement: The work is funded by the National Science Centre Poland (NCN) based on the decision number UMO-2021/43/D/ST5/00824. Kun Zheng acknowledges the financial support of research project supported by the program „Excellence Initiative – Research University” for the AGH University of Krakow.

Investigation of the properties of cathode materials with a double perovskite structure under the synergistic influence of defects and bismuth ions

Fangjun Jin[1],*, Wenjing Zhang[1], Yihan Ling, Kun Zheng[2]

Keywords: Solid oxide fuel cells, Double perovskite Cathode, bismuth, Electrochemical performance; CO_2 Tolerance

ABSTRACT

Development of new functional materials with improved characteristics for solid oxide fuel cells (SOFCs) and solid oxide electrolysis cells (SOECs) is one of the most important tasks of modern materials science. High electrocatalytic activity in oxygen reduction reactions (ORR), chemical and thermomechanical compatibility with solid electrolytes, as well as stability at elevated temperatures are the most important requirements for cathode materials utilized in SOFCs. Layered oxygen double perovskites $LnBaCo_2O_{5+\delta}$ (Ln = lanthanides including La, Pr, Sm, Nd, Gd, and Y) possess the complex of the above-mentioned properties, being one of the most promising cathode materials operating at intermediate temperatures. This work investigated the crystal structure, thermal, electro-transport-related, and other functional properties (including electrochemical performance in ORR) of defective and bismuth ion modified double perovskites as SOFCs. The introduction of cation defection and Bi^{3+} highly polarizable $6s^2$ lone pair electrons are likely to contribute to a high oxygen ion diffusivity. The main emphasis is placed on the state-of-art approaches to improving the functional characteristics of these complex oxides.

A simple way to tune the performance of $NdBaCo_2O_{5+\delta}$ (NBC) perovskite as a cathode by doping the Co-site with bismuth cation is reported [1]. Compared with the parent oxide, the obtained stabilized double perovskites $NdBaCo_{2-x}Bi_xO_{5+\delta}$ (x = 0.1 and 0.2; NBCB) show a much-improved electrocatalytic activity. Density functional theory results demonstrate that bismuth doping effectively reduces the formation energy of oxygen vacancies. Moreover, the bismuth doping of $NdBaCo_{2-x}Bi_xO_{5+\delta}$ cathode is much more robust against CO_2 than that of NBC cathode.

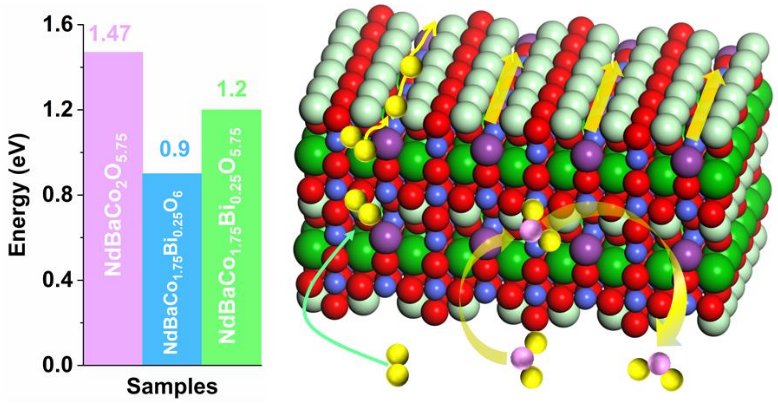

Figure 1. The formation energy of oxygen vacancies and schematic representation of a proposed reaction mechanism for the ORR and CO_2 tolerance on the NBCB cathode

New type of double perovskite composite cathode materials were prepared by

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introducing Ln (Ln = Pr and Nd) defect with bismuth oxide [2,3]. The introduction of a bismuth oxide trace effectively increased conductivity and reduced the thermal expansion coefficient. An excess cation-deficient double perovskite backbone and in situ exsolved perovskite nanoparticles modified by bismuth. The anisotropic growth of such self-assembled nanoparticles and the formation of multiple heterointerfaces exhibit an extremely strong activation effect. The in situ formed nanoparticles and cation-deficient parental perovskite significantly enhance the catalytic activity and durability of the cathode toward oxygen reduction. The structural stability and CO_2 tolerance of the cathode are greatly enhanced, which is attributed to the penetration of the high acidic Bi ions in the separated phase and the synergistic effect of the two-phase interface.

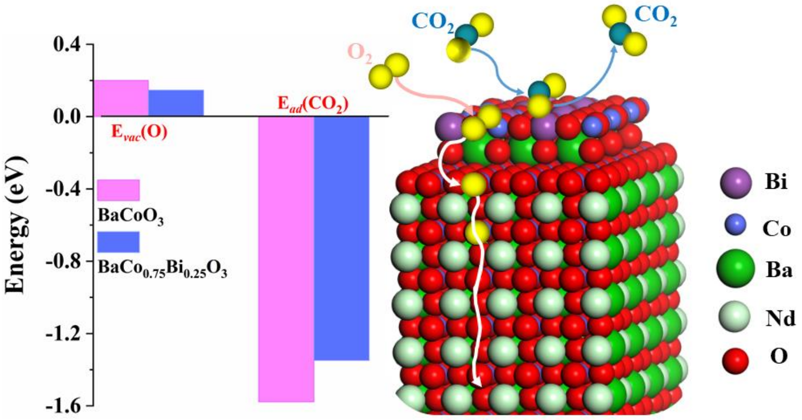

Figure 2. (a) The computed oxygen-vacancy formation energy and surface adsorption energies of CO_2 *for the* $BaCoO_3$ *and* $BaCo_{0.75}Bi_{0.25}O_3$*, (b) schematic representation of a proposed reaction mechanism for the NBC90+B cathode.*

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Tailoring negative thermal expansion coefficient materials for SOFC composite cathode with improved performance

Piotr Winiarz[1,*], **Jakub Fudalewski**[1], **Kun Zheng**[1]

Keywords: Solid Oxide Cells, negative thermal expansion, composites, cathodes

ABSTRACT

Long-term stability of Solid Oxide Cells (SOCs) is one of the major issues, that limits their commercial application. The main reason for possible degradation comes from the thermal expansion coefficient (TEC) mismatch between the electrode and electrolyte, which causes unwanted strain, cracks, and layer delamination. This problem could be solved by using negative thermal expansion coefficient materials (NTEs) which decrease their spatial dimensions with increasing temperature. This interesting property along with the high electronic conductivity was recently reported for $Sm_{1-x}A_xMnO_{3-\delta}$ (A = Zn, Cu; $x \leq 0.15$) perovskite-based oxides [1]. The addition of such materials to the chosen SOCs cathode allows obtaining composite-type electrodes which adjust the TEC to the chosen electrolyte material and diminish possible degradation mechanisms. Therefore, the appropriately designed and synthesized composite electrode should suitably lower the polarization resistance, and enhance the long-term stability, which in effect would greatly increase not only the performance but also the practical applicability of the SOC-based devices.

Double perovskite oxides from $REBa_{0.5}Sr_{0.5}CoCuO_{5+\delta}$ (RE: Pr, Nd, Sm, Gd) group are known for their high mixed ionic-electronic conductivity, as well as suitable electrocatalytic activity, and are reported as attractive oxygen electrode materials for SOCs [2,3,4]. In this work, those materials were prepared by the typical sol-gel method or the electrospinning method. Among initially studied compositions, $SmBa_{0.5}Sr_{0.5}CoCuO_{5+\delta}$ (SBSCCO) was found to be the best candidate, exhibiting demanded physicochemical and electrocatalytic properties. Also, this single-phase material is chemically stable and compatible with LSGM electrolyte. The total conductivity of SBSCCO is around 100 $S{\cdot}cm^{-1}$ between 300°C and 900°C, while if used as the oxygen electrode, the measured polarization resistance (Rp) in SBSCCO|LSGM|SBSCCO symmetrical cell was only 0.17 $\Omega{\cdot}cm^2$ at 800°C. The long-term stability tests showed that the relative increase of Rp is around 20% after 5 days at 700°C.

To further enhance the characteristics of the previously obtained SBSCCO electrode, composite electrodes with different wt% additions of $Sm_{0.85}Zn_{0.15}MnO_{3-\delta}$ (SZM15) or $Sm_{0.85}Cu_{0.15}MnO_{3-\delta}$ (SCM15) were prepared. The dilatometry measurements confirmed the negative TEC for those materials, ranging from -0.1×10^{-6} K^{-1} to -11×10^{-6} K^{-1} between the 200-900°C range. Also, the total conductivity of SZM15 was found to be around 20 $S{\cdot}cm^{-1}$ at 900°C. The preliminary results show that the Rp of the composite electrode with 10 wt.% addition of SZM15, as measured in the SBSCCO:SZM15|LSGM|SBSCCO:SZM15 symmetrical cell in the 700-900°C range, was significantly lower when compared with the unmodified SBSCCO electrode. For instance, Rp at 800°C was 0.12 $\Omega{\cdot}cm^2$ giving a 30% relative decrease. Additionally, the I-V characteristics were measured for commercial anode-supported fuel cells comprising Ni-YSZ|YSZ support, GDC10 buffer layer, and the SBSCCO:SZM15 composite electrode. The maximum peak power density recorded at 800°C was 850 $mW{\cdot}cm^{-2}$, which is around 60% higher when compared to the same cell prepared with the SBSCCO electrode without NTE addition.

All the obtained results clearly show that the state-of-the-art innovative application of NTEs in SOCs indeed allows for decreasing the TEC of the composite and adjusting it to

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the solid electrolyte, but also enables a significant decrease of the polarization resistance. Further experiments are ongoing, regarding the long-term performance of the composite electrodes, SEM and TEM measurements involving the electrolyte/electrode interface.

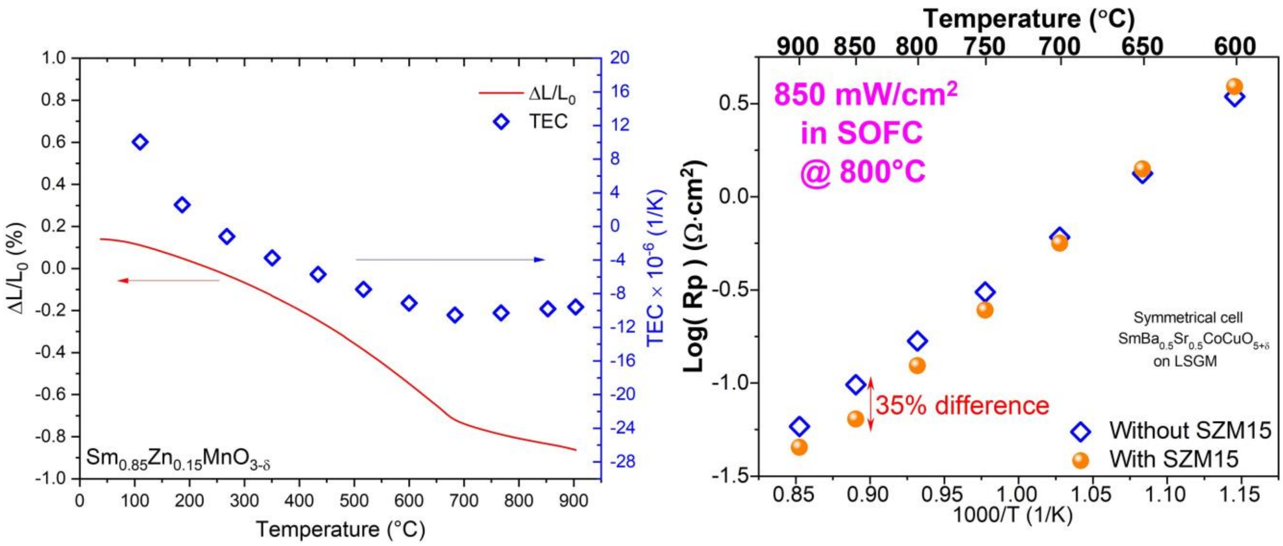

Figure 1. a) relative elongation vs temperature (left axis) and calculated TEC (right axis) for Sm$_{0.85}$Zn$_{0.15}$MnO$_{3-\delta}$, b) polarization resistance on the symmetrical cell with and without SZM15

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From waste to functional materials - valorization of fly ashes from energy sector

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Keywords: valorization of fly ashes, functional materials, catalysts, zeolites, circular economy, sustainability

ABSTRACT

Despite many recent recomendations to meet current environmental goals and to become more sustainable, it is not easy to replace worldwide conventional energy sources with renewable ones. Combustion of non-renewable fuels still accounts for an important part of energy production both nowadays and most probably also in the coming years. It is noteworthy that combustion of solid and liquid fuels as well as of biomass is associated not only with possible gaseous emissions but also with generation of various solid waste like ashes, fly ashes or slag. They are unavoidable by-products of the industrial technologies of energy production from coal, heavy oil or biomass.

This work is focused on fly ashes (FAs) and on the advanced routes of their non-conventional use in both material chemistry and catalysis. FAs generated by energy sector in the amount of approximately 600-700 million tons per year, should absolutely be further exploited, recycled, or stored (properly protected against leakages of noxious components to groundwaters) to reduce their potentially negative impact on the environment. The most desirable and sustainable (both ecologically and economically) way of managing this type of combustion by-products is e.g. their use for synthesis of advanced functional systems of market potential. Due to relatively small particle sizes, ranging from 1 to 500 μm fly ashes rise in the flue gas stream and leave the combustion chamber with tale gases. They are subsequently captured from the flue gas streams - most often with the use of electrostatic precipitators. The ash grains generated from coal combustion contain mainly silicon, aluminum, and iron in their elemental composition. The additional components are primarily calcium, sodium, potassium, magnesium and titanium. Among the trace elements such metals as nickel, manganese and lead can also be identified. Unburned fuels may also be found in FAs. The presence and amount of carbonaceous residuals in FAs is a measure of combustion efficiency [1].

Fly ashes can be considered as complex composite materials. It is thus important to exploit them properly, basing on the detailed analysis of their physicochemical parameters and to modify them in line with their most promising valorization opportunities [2]. Due to their specific physical and chemical properties, fly ashes can be widely used as anthropogenic raw materials to synthesize zeolites, catalytic materials or sorbents. The associated economic benefits related to efficient use of fly ashes generated from energy sector may further increase their circular exploitation.

This work presents the results of structural, textural and functional studies of fly ashes from the energy sector, generated from the combustion of two types of fossil fuels: heavy oil fractions and hard coal. Our results confirm the high potential of this type of

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anthropogenic raw materials to synthesize at least two types of systems of high catalytic relevance: zeolites and oxide supported systems. In the latter case, both the carrier and the active phase, containing such components as vanadium, nickel, iron and copper, can be obtained directly from fly ashes (Fig. 1A). For the final catalytic systems, the chemical composition was determined by XRF method, the phase composition was examined by using the XRD and RS methods, the textural properties were analyzed by using the SEM/EDS method and porosimetry, and the functional properties were determined by DRIFT and UV/Vis-DR methods.

Due to the diverse composition of the starting fly ashes, syntheses of the tailored structures are very challenging and must be preceded with a thorough analysis of such parameters characterizing the ashes as e.g.: the Si/Al element content ratio, the presence of iron and carbon residues. The information about mineral and phase compositions as well as on the content ratio of glassy to crystalline phases may also be essential. FAs are characterized by a high amount of silicon and aluminum. These elements occur both in the form of amorphous/glassy aluminosilicates, which are the building material of spherical grains, called cenospheres, and in fully crystalline forms of quartz and mullite.

While the synthesis of zeolites with 3D structures from FAs is relatively well mastered, a synthesis of layered systems (2D), with active centers located in the outer surface layers (very attractive from the catalytic viewpoint) is much more demanding. One of our goals in this work was to check the possibility of synthesizing zeolites of various structures from fly ashes (Fig. 1B) and to indicate main parameters controlling those preparative procedures. And so, three different synthetic paths have been successfully tested, leading to: classic NaX-type zeolites (3D) [1], MCM-22 layered zeolite precursors (3D → 2D) and bifer-type layered (2D) structures [3]. Obtaining the latter is a significant step towards designing the new synthetic advanced pathways for the use of fly ashes.

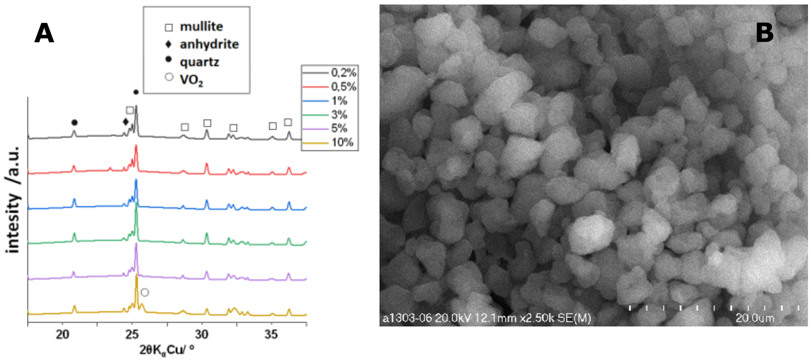

Figure 1. XRD patterns of supported oxide catalysts synthesized from FAs (A), morphology of a zeolite obtained from FAs (B).

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Sustainability of methanol production via catalytic hydrogenation of CO_2

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Keywords: methanol, heterogeneous catalysis, hydrogenation of CO2, technology, sustainability

ABSTRACT

Carbon dioxide belongs to powerful greenhouse gases and its global emission have been increased by over 60% in the last 30 years [1], substantially contributing to anthropogenic climate changes. Thus, there is a vital necessity not only to strongly reduce the emissions of CO_2 arising mainly from various fossil-fuel-combustion-related sources, but also to find practical ways to efficiently manage at least a part of the generated CO_2 in industrially feasible and economically viable technologies. Such approach is absolutely necessary to decrease the risks associated with the observed climate changes. Of the various methods of carbon dioxide processing, catalytic valorization offers numerous benefits, including its efficiency, high applicational potential, and attractive possibilities to convert CO_2 to many valuable products, including methanol, synthesis gas, dimethyl ether, low hydrocarbons etc. Many of these products can be considered as worthwhile components of synthetic fuels.

There is currently a high potential for technological expansion in the fields of CO_2 utilization and its efficient valorization, as the approximate 200 Mt of CO_2 that are currently utilized each year account for less than 0.01% of the total CO_2 emissions produced globally, across all industries [2]. The production of CO_2-derived chemicals and fuels is in high-demand and this market is still growing. Without any doubt, there is an increasing need for effective and massive use of CO_2. Such processes can meet various socioeconomical and environmental benefits. However, many of the technologies concerned remain still at rather early stages of the full scale implementation, regarding their relatively low technology readiness levels. It is thus crucial to pay an attention to the overall sustainability of the proposed solutions that have to fulfill simultaneously environmental, economic and social criteria. Moreover, the current carbon capture and utilization (CCU) technologies are still insufficiently known outside the scientific community, which may create specific socioeconomic barriers. The social acceptance, reasonable system of incentives for industry, and public support to produce and use such CO_2-derived products, like e.g. methanol, are key factors decisive for successful commercialization of CO_2 valorization. Methanol has an average market selling price of 400 USD per tonne, and the cost of production from CO_2 is roughly 510 USD per tonne [2]. It is however expected that the costs of production will go down with current advancements in process technology, carbon capture, and the implemented efficient catalytic solutions.

The main aim of the current work was to analyze the sustainability aspects associated with the CO_2 hydrogenation pathway towards methanol with a particular attention paid to both material and process conditions in order to identify key advantages and challenges of this process (Fig. 1), considered as the most important technological part of an integral value chain. The operational aim was to determine principal synthetic parameters to obtain

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copper- or copper and zinc-based catalysts supported on both Al_2O_3 or cenospheres from energy sector optimal for low-temperature CO_2 hydrogenation.

All crucial synthetic steps to obtain efficient Cu- and/or Cu-Zn-based catalysts as well as the conditions of the catalytic tests in hydrogenation of CO_2 have been analyzed from the viewpoint of environmental and socioeconomic sustainability. Structural, textural and functional properties of the applied catalytic systems have been characterized by XRD, RS, SEM/EDS, porosimetry, DRIFT and UV/Vis-DR techniques. Additionally, the effect of support has been elucidated, because apart from the g-Al_2O_3-supported samples also those supported on commercial cenospheres of various granulation were synthesized.

Catalytic tests in methanol synthesis via hydrogenation of CO_2 have been performed for samples containing 5 % of the active phase in a batch reactor of 30 cm^3 volume using a H_2/CO_2 mixture of a 3:1 ratio. The tests were carried out at temperature 200 °C under the pressure p = 3,5 MPa. The concentrations of reactants at the reactor outlet were determined by gas chromatography.

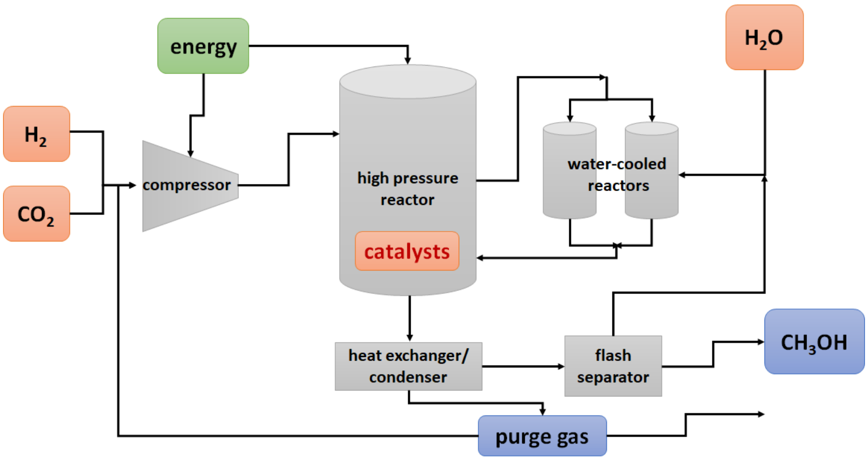

Figure 1. Simplified scheme of industrial instalation for CO_2 hydrogenation [2].

The obtained results validated the possibility to control at the preparation step architecture of the catalytically active phase to improve final properties of the tested materials. They also confirmed the potential of cenospheres to serve as catalytic supports. Moreover, utilizing the latter materials, one can reach more advantageous effects in terms of environmental and/or economic goals. And so, catalytically active phases can be more effectively used by deposition of smaller amounts of active components on such cheap supports, in comparison to the coprecipitated CuO-ZnO-Al_2O_3 systems conventionally used in hydrogenation of CO_2. In this way both reduction of operational costs and lower consumption of materials can be reached. It is also noteworthy, that in the approach described above we are able to exploit anthropogenic raw materials that would otherwise be treated as waste products. With a proper information on the described processes referring to principles of circular economy and of recycling of materials of catalytic importance, a social benefit for environmentally-minded companies could be provided.

Current studies suggested that appropriate selection and optimization of the catalytic system can reduce both energy and material consumption associated with industrial production of methanol from CO_2. The presented approach seems to be distinctly much more sustainable than the conventional one based on the use of CuO-ZnO-Al_2O_3 coprecipitated catalytic systems for industrial CO_2 hydrogenation.

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ENERGY FUELS ENVIRONMENT EFE2024

26-28 JUNE 2024, KRAKOW, POLAND

Use of cenospheres from fly ashes as components of oxide catalysts active in reactions of environmental importance

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Keywords: fly ashes, cenospheres, oxide catalysts, functionalization, surface architecture, sustainability

ABSTRACT

Fly ashes (FAs) generated in a mass scale from energy sector can be a source of many valuable components useful e.g. in synthesis of advanced functional materials. Catalysts also belong to the latter group. Cenospheres can be an interesting example of such useful FA components of high application potential. From a catalytic viewpoint, these spherical structures, easily extracted from fly ashes, exhibit quite attractive features: high thermal stability, good mechanical strength and resistance to chemical corrosion. Certain problem can be however associated with relatively low specific surface area of cenospheres, usually not exceeding several m^2/g, that slightly lowers the potential of using cenospheres as catalytic carriers. The surface of cenospheres formed at temperatures above 1200°C is rich in silicon, aluminum, iron and alkali metals. From a material chemistry perspective, cenosphere surface can be considered as a composite, integrating glassy amorphous structures coexisting with crystalline domains. Such structural surface heterogeneity can be used for deposition of oxides playing a role of catalytically active phases. Such modification results in partial increase of surface area of cenospheres. The interaction of cenospheres with the deposited oxide active phases allows them to be effectively functionalization in order to obtain catalysts active in such redox reactions of significant environmental importance, such as: hydrogenation of CO_2, soot combustion, or selective catalytic reduction of nitrogen oxides.

The main elements present in the cenospheres are a mixture of aluminosilicates with moderate amounts of Ca, Fe, K, Mg, rather limited contents of Na, Ti, S, P, and various trace elements. These elements do not always occur in the cenospheres in the form of corresponding oxides but they are a mixture of various crystalline and amorphous phases, as mentioned earlier. And so, crystalline phases contain mainly calcite and mullite whereas the glassy phase consists of aluminosilicates (together >10%) and represents the main structural components of the cenosphere. Other forms occurring on the surface of cenospheres may be quartz, cristobalite and soot (>1-10%) [1]. The skeleton of cenospheres is composed of aggregates of fine mullite, cristobalite and quartz needle crystals growing in their vicinity, or is composed of clusters of acicular crystallites. Such structure ensures the stability of cenospheres over a wide temperature range. The framework of the cenospheres is closed with approximately 90% by weight of the amorphous glassy phases, which provides a smooth surface.

Depending on the method of separation, drying and storing the material, other minerals may also occasionally appear on the surface of cenospheres, such as gypsum, portlandite, plagioclase, K-feldspar, dolomite and some gypsum and Fe oxides (mainly magnetite) (0.5-1 %). As cenospheres dry, gypsum, portlandite and brucite may transform into the more stable form of the corresponding carbonates, namely calcite, dolomite and

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possibly magnesite, formed by the absorption of carbon dioxide from the air. Such structural details do not remain unaffected catalytic properties and especially - the nature and strength of interaction between cenosphere surfaces and the deposited phases, introduced to obtain catalytically satisfactory functionalization of cenosphere surfaces.

The aim of this research was to demonstrate the usefulness of commercial cenospheres of diameters 150 and 300 μm, functionalized by wet impregnation with aqueous solutions of copper(II) precursor or copper(II) and zinc precursors, in environmental catalysis. Impregnated samples were calcined at 400°C 4 hours to obtain final catalytic systems. The samples containing 0.5-10.0 mol.%. of copper or a combination of 0.3-6.0 mol.%. of copper and 0.2-4.0 mol. % of zinc were subjected to the in-depth characterization using the following methods: XRF, XRD, RS, SEM/EDS, BET, DRIFT and UV/Vis-DR. The catalytic activity of selected samples was tested in the reaction SCR NO_x, using ammonia as a reducer.

Structural XRD and RS studies confirmed that interactions between cenosphere surfaces and the deposited phases, containing various metal ions, were rather weak, favoring the formation of CuO and ZnO three-dimensional nanorystallites even at such low concentrations of the deposited phases as 0.5 mol. % of Cu or 0.3 mol. % of Cu and 0.2 mol. % of Zn (see Fig. 1 below). It was thus inferred, that cenospheres belong to the supports limiting natural tendency of the deposited oxide phases to expand. Simultaneously, as revealed by DRIFT, due to relatively many different stabilization sites, heterogeneity of hydroxyls stabilized on the surface of cenosphere-supported catalysts was quite strong.

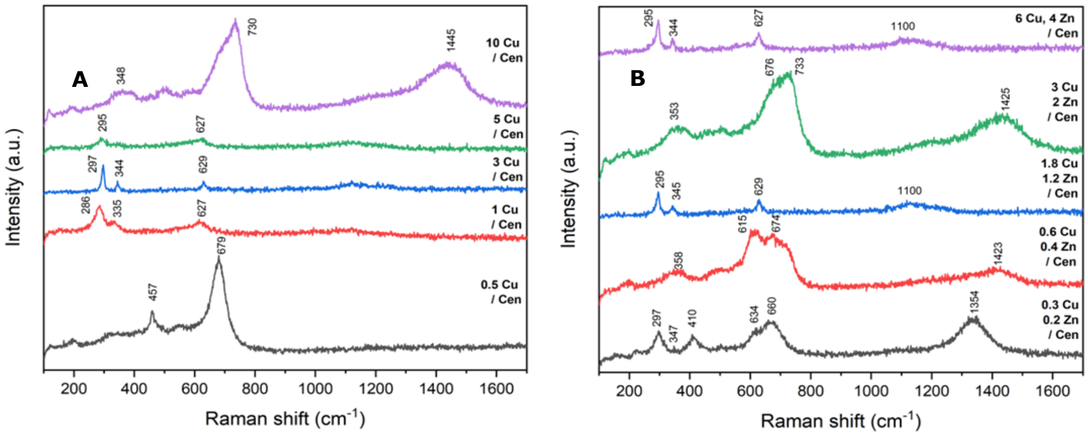

Figure 1. Raman spectra of the cenosphere-supported copper- (A), copper and zinc-(B) containing catalysts [2].

The performed catalytic tests confirmed the high application potential of cenospheres as components of heterogeneous catalysts. Moreover, the use of such materials, derived from fly ashes, being in turn commonly generated waste materials, to obtain valuable final products is an excellent example of an approach which remains in full agreement with the principles of circular economy.

Acknowledgements: the research has been supported by a grant from the Priority Research Area Anthropocene (FP Man-Mind-Environment Hub) under the Strategic Programme Excellence Initiative at the Jagiellonian University. Contribution of P.R. to this work was also supported in the framework of POWR.03.02.0000I004/16 and of Talent Management POB Anthropocene grants.

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Redox-metal-doped potassium glasses for catalytic soot abatement

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Keywords: catalytic soot combustion, potassium silicate glasses, structural modifications by doping, aliovalent redox metals, potassium stability

ABSTRACT

Abatement of emission of soot-containing particulate matter is one of the most important challenges of nowadays society, because of their strongly negative influence on the respiratory, cardiovascular, and nervous systems of humans as well as on our reproductive health. Besides the elimination of so-called low-emission sources, success in emission reduction is limited by the inefficient removal of soot from mobile sources, like cars, ships, and planes as well as of soot generated by diesel engines in technological drives. The most promising way to meet both ecological and socio-economical goals is the usage of catalysts able to combust soot at relatively mild conditions efficiently. Alkali-contained catalysts seem to be an effective and economical solution, however, due to the high volatility of alkali metals, an oxide matrix to stabilize them is needed [1]. Besides of crystalline oxides, supported and nanostructured, there are glassy systems, that are not sufficiently investigated regarding their application potential in the field of soot combustion. This work aimed to investigate how doping by metals with prominent redox properties (Ti, V, Mn, Fe, Co, Ni, Cu, Zr, Ce, Pb, Bi) can influence the catalytic properties of potassium silicate glasses.

An undoped glass ($25K_2O$-$59SiO_2$-$16CaO$ % mol.) was synthesized from SiO_2, K_2CO_3, and $CaCO_3$ by melting at 1345°C for 1 hour. The redox-metal-doped glasses were synthesized by remelting the undoped glass with a corresponding dopant oxide (TiO_2, V_2O_5, MnO_2, Fe_2O_3, CoO, Ni_2O_3, CuO, ZrO_2, CeO_2, PbO_2, Bi_2O_3) at 1340°C for 0.5 hours [2]. The structure of the investigated samples was examined by X-ray diffraction, Raman, and infrared spectroscopies, chemical composition was studied by X-ray fluorescence, whereas functional features were examined by diffuse reflectance infrared spectroscopy, and dopant speciation by both UV/Vis diffuse reflectance and X-ray photoelectron spectroscopies. The morphology of the investigated samples was examined by scanning electron microscopy. Potassium state and stability were investigated by the Species Resolved-Thermal Alkali Desorption method. The catalytic activity of the investigated glasses was tested both in *tight* and *loose contacts*, in the atmosphere containing 10% of O_2 in He and 0 or 500 ppm of NO.

The amorphous character of the investigated samples was confirmed by XRD, RS, and FTIR. However, in the case of Ni-, Zr- and Ce-doped samples also nanocrystalline phases of NiO, ZrO_2, and CeO_2, respectively, have been identified. Chemical analysis by the XRF confirmed the desired nominal composition of the synthesized glasses. The oxidation states

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of the introduced dopants determined by UV/Vis-DR supported by XPS were revealed as Ti(+4), V(+5), Mn(+2/+3), Fe(+3), Co(+2/+3), Ni(2+), Cu(+2), Zr(+4), Ce(+3/+4), Pb(+2), and Bi(+3). Strong hydroxylation and carboxylation of the glass surfaces were confirmed by the DRIFT method, which can be explained as a result of potassium interaction with CO_2 and H_2O from the air. It was also found by the SEM that potassium carbonates can be observed on the surface of the samples for which higher stability of potassium was established. Potassium thermal stability depended however on the presence of dopants, and most of them led to potassium desorption flux increment.

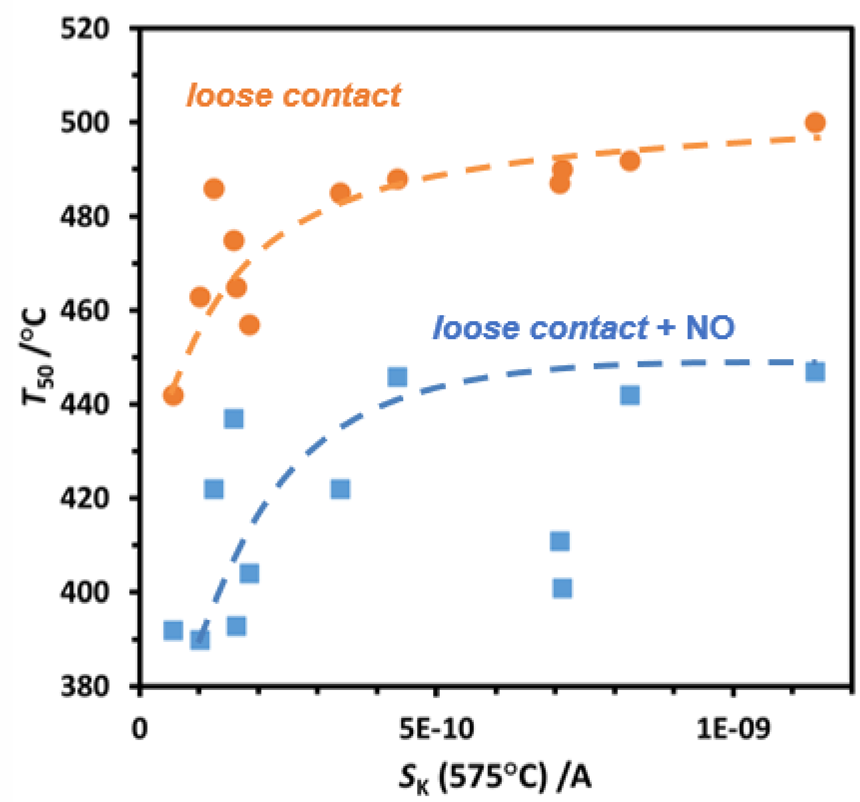

Figure 1. Correlation between the determined activity (as the temperature of 50% conversion of soot) of redox-metal-doped potassium glasses and their thermal potassium stability (as potassium atoms flux at 575°C)

All investigated catalysts showed distinctly high activity in soot combustion, regardless of the performed test conditions. However, regarding catalytic soot combustion, as the most interesting dopants Co, Cu, Zr, and Pb can be considered. The correlation between catalytic activity in deSoot (as a temperature of 50% soot conversion) and potassium thermal stability (as potassium atoms flux at 575°C) was established (Figure 1). Based on these results, it can be stated, that higher stability of potassium goes together with higher catalytic activity of the investigated samples.

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Optimization of potassium concentration in Ni-K/CeO$_2$ model catalyst for dry methane reforming

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Keywords: dry methane reforming, catalyst stability, potassium, syngas

ABSTRACT

One of the most burning problems to be solved as soon as possible is the efficient reduction of greenhouse gases (GHGs) emissions. Among all others, carbon dioxide and methane belong to the most problematic emissions, regarding their GHG potentials and global volume of emissions. The most sustainable way of GHGs valorization is their conversion to valuable products. A good example of such an approach can serve the so-called dry methane reforming (DMR), in which CO$_2$ and CH$_4$ are simultaneously converted to syngas (i.e. to H$_2$ and CO mixture). However, the development of a cheap, active, and stable catalyst for DMR is quite demanding. Alkali doping seems to be a promising way to increase the resistance of the DMR catalysts to carbon deposit formation. This work aimed to investigate the influence of potassium content on the activity and stability of the Ni-K/CeO$_2$ model catalyst.

As a starting composition, Ni/CeO$_2$ with 3% of active phase, was chosen. Samples of parent catalysts were impregnated with KNO$_3$ aqueous solution with proper concentrations, to achieve potassium contents from 0 to 10 wt. % in the final samples. Catalysts were characterized by XRD, RS, SEM, N$_2$-BET, DRIFT, UV/Vis-DR, and XPS. Catalytic tests were performed in 2.5% CO$_2$ and 2.5% CH$_4$ in Ar. Reaction products were analyzed by the GC/TCD method. Stability tests were performed as long-term experiments at 750°C.

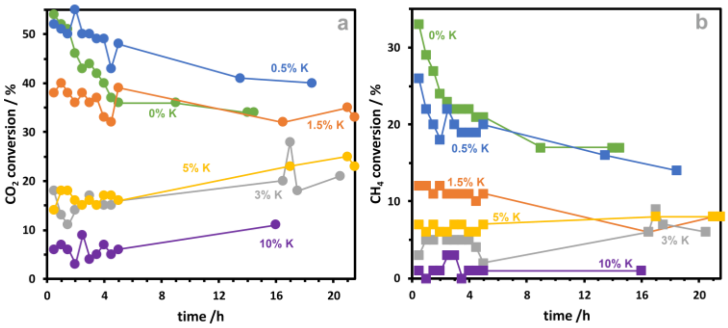

Figure 1. Stability test of Ni-xK/CeO$_2$ (x = 0-10%) catalysts monitored as time dependence of CO$_2$ (a) and CH$_4$ (b) conversions.

The introduction of potassium did not influence significantly neither the bulk nor surface structure of the Ni/CeO$_2$ catalysts. However, it led to a distinct decrement in the activity of catalysts dependent on the potassium content. The performed stability tests (Figure 1) showed that the presence of potassium improved the stability of all catalysts although simultaneously their catalytic activity tends to drop very strongly. The optimal concentration of potassium, regarding both activity and stability, should be fixed at a relatively low level (0.5-1.5%).

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Tuning *in situ* exsolution of nanocatalysts in defect engineered double perovskites for Symmetrical Solid Oxide Cells

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Keywords: Nanocatalysts, Symmetrical solid oxide cell, Perovskites, *in situ* nanoexsolution

ABSTRACT

The Solid Oxid Cells (SOCs) with symmetrical configuration can function in a fuel cell or electrolysis mode, depending on the current demand. Applying the same materials in both cathode and anode reduces the number of cell components and simplifies the cell manufacturing process. However, electrode material candidates for symmetrical SOCs must meet certain requirements like excellent redox stability and electrocatalytic activities. The design of materials capable of *in situ* exsolution of nanoparticles for electrodes is regarded as highly advantageous. The *in situ* exsolved metallic nanoparticles can enhance catalytic activities and stability contributing to the improved performance of SOCs [1, 2]. Apart from surface modification, the exsolution process has a significant impact on the bulk modification of electrode material by increasing the concentration of oxygen vacancies within the perovskite structure. The generation of oxygen vacancies can be particularly advantageous for electrode materials because it creates fast channels for oxygen ion diffusion, promoting higher ionic conductivity [3, 4]. Therefore, in this work $Ln_{0.9}Ba_{0.9}Mn_{1.8-x}Fe_xCo_{0.1}Ni_{0.1}O_{6-d}$ (Ln = Sm and Nd) materials with Fe-doping at Mn-site and *in situ* exsolution of nanoparticles have been designed as stable electrode materials for symmetrical SOCs.

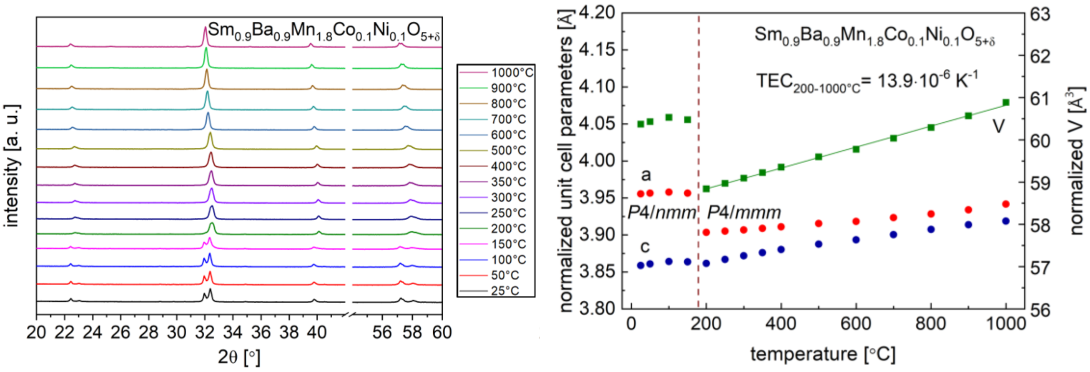

Figure 1. HT-XRD diffractogram recorded in the air on heating up to 1000 °C for $Sm_{0.9}Ba_{0.9}Mn_{1.8}Co_{0.1}Ni_{0.1}O_{5+\delta}$ and normalized unit cell and volume dependence on temperature [2].

The perovskite oxides from $Ln_{0.9}Ba_{0.9}Mn_{1.8-x}Fe_xCo_{0.1}Ni_{0.1}O_{6-\delta}$ (Ln=Sm and Nd) system

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with exsolved nanocatalysts have been tuned as electrode materials in symmetrical SOCs. Obtained compounds crystallize in *P*4/*nmm* and P4/*mmm* space group systems and are redox stable both in oxidizing and reducing conditions. It has been recorded that the continuous phase transition at around 200 °C is characterized by the second order. Oxides belong to a double perovskite structure which favors the fast oxygen transport. Moreover, it has been found that A-site nonstochiometry defect design facilitates *in situ* exsolution process of ternary Fe-Co-Ni alloy nanoparticles in the atmosphere of 5 vol.% H_2/Ar. The thermal expansion coefficient values are very close to the most commonly used electrolytes (including $La_{0.9}Sr_{0.1}Ga_{0.8}Mg_{0.2}O_{3-d}$ and $Ce_{0.8}Gd_{0.2}O_{2-d}$) thus giving mechanical compatibility in SOCs. Very low electrode polarizations of symmetrical cells with $Sm_{0.9}Ba_{0.9}Mn_{1.8-x}Fe_xCo_{0.1}Ni_{0.1}O_{6-d}$ measured in 5 vol% H_2/argon indicate that the investigated perovskite is particularly of interest for the anode application.

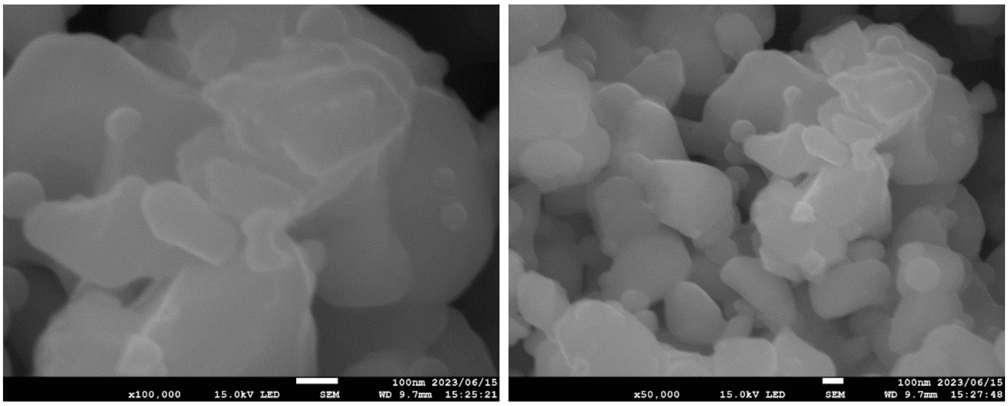

Figure 2. SEM micrographs of $Sm_{0.9}Ba_{0.9}Mn_{0.9}Fe_{0.9}Co_{0.1}Ni_{0.1}O_{5+\delta}$ oxide with in situ exsolved nanoparticles after reduction in pure H_2 at 800 °C.

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New energy materials for smart windows of smart cities and green mobility

Verónica de Zea Bermudez[1]

Keywords: smart windows, smart cities, solar energy

ABSTRACT

Europe is committed to overcoming energy consumption using the smart city concept. Smart cities require the integration of smart solutions for renewable energy, where buildings stand as high consumers of this resource. The development of innovative solutions, healthy materials, and intelligent technologies to be integrated into buildings are essential in the pursuit of the main goals of the current European policies as a way to implement the United Nation's 2030 Agenda and the Sustainability Goals. Smart cities are pivotal to achieving the milestones of the 2030 and 2050 agendas.

Buildings are the largest energy consumer and one of the largest CO2 emitters, being responsible for 40% of energy consumption and 36% of greenhouse gas emissions. Half of this energy consumption is associated with heating, cooling, and lighting.

Windows are known to impact dramatically on the mitigation of the building energy consumption. Transitioning from static to dynamic (or smart) windows is an extremely attractive technological solution, which may result in a reduction of 40% of the building's energy needs [1]. Smart windows allow adjusting the sunlight and solar heat inflow in real-time, at the occupant's choice, independently of the geographical location, climate region, season of the year, or building's orientation, thus increasing the building energy performance by minimizing heating and cooling needs indoors, providing more visual and thermal comfort, improving outdoors view, and imparting suitable aesthetic features.

Herein advanced smart windows for the next generation of buildings and green vehicles, based on a judicious integration of thermotropic and electrochromic devices, luminescent solar concentrators, and commercial photovoltaic cells, are reported [2-5].

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Boosting the electrochemical performance of oxygen electrodes via the formation of LSCF-$BaCe_{0.9-x}Mo_xY_{0.1}O_{3-\delta}$ triple conducting composite for solid oxide fuel cells

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Keywords: Solid oxide fuel cell, Oxygen reduction reaction, Composite cathode, Broadband electrochemical impedance spectroscopy, Activation energy

ABSTRACT

The solid oxide fuel cell (SOFC) is regarded as a promising technology for the conversion of chemical energy to electrical energy via the oxidation of a fuel. Currently, SOFCs based on proton-conducting electrolytes attract the attention of researchers around the world due to their high ionic conductivity at relatively low temperatures in the range from 500 to 600 °C. Multiple studies have been reported with the aim of decreasing the operating temperature and enhancing the long-term stability of SOFCs [1-3]. SOFCs with a proton-conducting electrolyte (H–SOFC) are superior to SOCFs based on typical oxide ion conducting electrolytes, as they exhibit relatively high energy efficiency and low activation energy. As discussed above, BCY is one of the most promising compounds in this group [4]. In Part I of our work [5], we successfully synthesized a proton-conducting BCY electrolyte by introducing small Mo admixtures, forming $BaCe_{0.9-x}Mo_xYO_{3-\delta}$ (BCM_xY), achieving good ionic conductivity at lower sintering temperatures. This accomplishment addresses a critical challenge in SOFC technology. In the present Part II of the study, we introduce a novel approach by creating a composite of LSCF with BCM_xY, effectively addressing the critical challenge of obtaining a triple-conducting material (conducting H^+, O^{2-}, and e^-). This marks a significant advancement in the field, allowing the efficient utilization of the entire electrode volume. To support the need for such innovation, we provide a concise overview of challenges faced in traditional composite electrodes and the importance of obtaining a triple-conducting material.

In the present work, we fabricated LSCF-$BCM_{0.025}Y$ triple-conducting composite as efficient and durable cathodes for boosting the electrochemical performance of intermediate-temperature SOFCs (IT-SOFCs). The formation of the LSCF-$BCM_{0.025}Y$ composite enhances both the three-phase reaction interface length and the concentration of oxygen vacancies, contributing to improved dissociation rates and enhanced oxygen adsorption. The desired characteristics, including density, structure, composition, electrochemical performance, and thermal stability, have been confirmed through a comprehensive set of analyses including scanning electron microscopy (SEM), transmission electron microscopy (TEM), X-ray diffraction (XRD), energy-dispersive X-ray spectroscopy (EDS), Fourier-transform infrared spectroscopy (FTIR), electrochemical impedance spectroscopy (EIS), and thermogravimetric analysis (TGA) coupled with differential scanning calorimetry (DSC), respectively. The cell configuration of Ni-YSZ | BCZY | LSCF-$BCM_{0.025}Y$ exhibited a remarkable maximum power density (MPD) of 418.7 $mW \cdot cm^{-2}$, which is approximately 29 % higher than that achieved with a typical LSCF cathode

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(325.6 mW·cm^{-2}) at an operating temperature of 600 °C. The outstanding performance and enduring stability of the LSCF-BCM$_{0.025}$Y composite over a 500 h period demonstrate its potential as a promising cathode material for intermediate-temperature SOFCs.

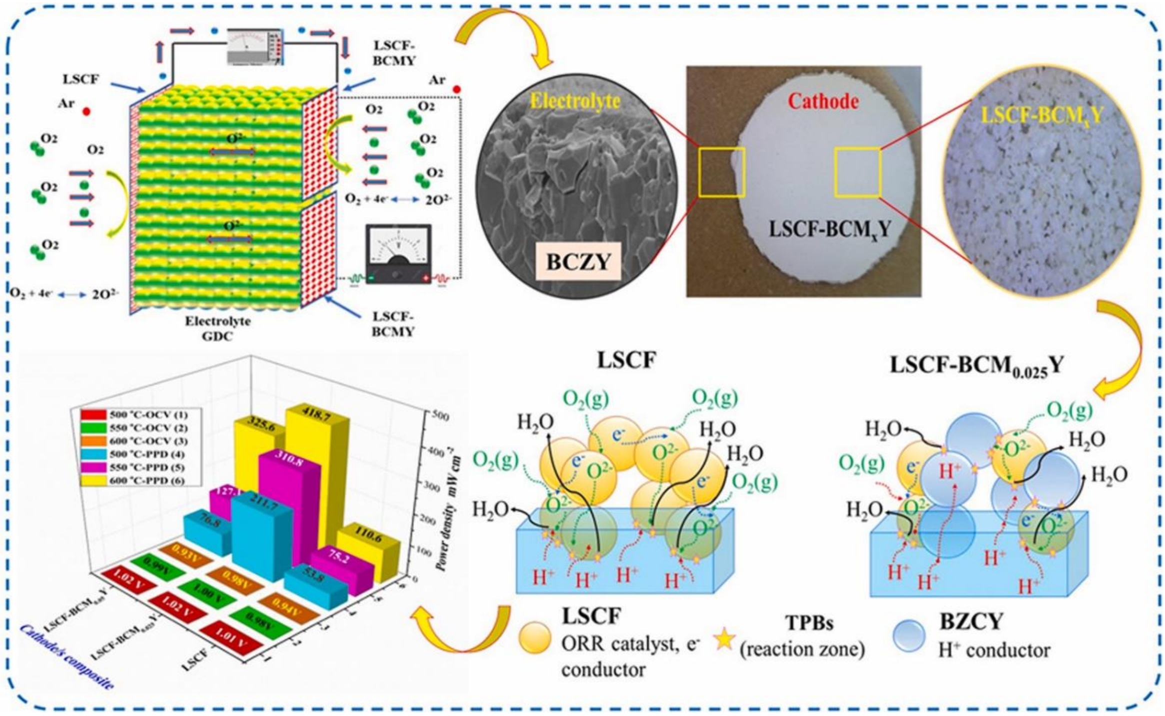

Figure 1. Graphical Abstract of Oxygen electrodes for SOFCs.

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Application of the GC-MS/MS method for the determination of hydroxyl derivatives of PAHS in particular matter

Karolina Cwynar[1], **Katarzyna Styszko**[1]*, **Zuzanna Prus**[1], **Laura Frydel**[1]

Keywords: particular matter, OH-PAHs, gas chromatography

ABSTRACT

Polycyclic aromatic hydrocarbons (PAHs) and their hydroxyl derivatives have a negative impact on the environment and health due to their toxicity. PAHs and their hydroxyl derivatives occurring in the atmosphere, settling on particular matter (PM) found in the air. This case is focused on determination of concentration of OH-PAHs contained in particular matter (PM_{10}) using Gas Chromatography-Mass Spectrometry (GC-MS). In this study 24 samples were used: 12 from the summer period and 12 from the winter period in order to compare concentrations depending on the season. The most common OH-PAHs: Fluoren–2 -ol (2-OH-FLU), Pyren-1-ol (1-OH-PYR), Naphtol-1-ol (1-OH-NAP), Naphtol-2-oh (2-OH-NAP) and Benzo[a]pyren-3-ol (3-OH-BaP) were chosen as examples of OH-PAHS group. To collect particular matter presence in the air a dust collector equipped with an air flow stabilizer was used and placed on a 3-story building at Kawiory Street in Krakow. The filters were extracted with dichloromethane and cyclohexane, extracts were evaporated and analyzed by GC-MS. The developed method allows for monitoring OH-PAHs in suspended dust, allowing for the assessment of the impact of air quality on the environment and human health.

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Process water tendency assessment to generate fouling deposits on heat exchangers

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Keywords: process water, fouling, deposits on heat exchangers

ABSTRACT

Process water plays an extremely important role in many industrial branches - it powers devices, is used in the production of goods, cools and heats. Particularly noteworthy is the use of process water in the refining industry and in power plants or combined heat and power plants, where highly efficient heat exchangers and a low tendency of water to form deposits on the heat exchange surface (fouling) are required. Fouling reduces heat transfer, which creates enormous operational difficulties, economic losses and leads to more frequent renovation downtime. The decrease in the thermal efficiency of exchangers as a result of the presence of fouling deposits also has a negative impact on the environment due to increased energy consumption and the release of greenhouse gas emissions. Estimates of the additional energy demand caused by fouling range from as much as 10% to over 30%. Preventing or reducing fouling is cheaper and more effective in maintaining heat exchanger performance than removing deposits and cleaning the exchangers. For this purpose, laboratory tests are carried out to assess the tendency of process water to foul. Based on the laboratory test results, decisions are made regarding the desired level of water treatment.

In this paper, a new methodology was developed for assessing the tendency of process water to foul using the FALEX apparatus (Falex Thermal Fouling Tester Refinery Process Analyzer), allowing for the comparison of the tendency of various process waters to form deposits on heat exchangers. The principle of the method is to simulate the fouling when the tested water sample flows through a disposable heat exchanger, which is dismantled after the test, and the deposits created on its surface are assessed by weight. The research material consisted of eight samples of model waters (tap, mineral and spring waters), differing in their chemical composition - different ion contents: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^-, SO_4^{2-}, Cl^-, F^-, including two samples of water additionally contaminated with hydrocarbons and hydrochloric acid. The tested water samples were introduced in the same amount into the FALEX apparatus, then the fouling phenomenon was simulated according to the developed research methodology, with three test repetitions for each sample. Deposits obtained during tests on research heat exchangers were weighed with an accuracy of 0.01 mg in order to assess the tendency of a given water sample to foul. Additionally, in order to assess the structure of the obtained fouling deposits, obtained deposits were analyzed using optical microscopy and infrared spectrometry. It was found that highly mineralized waters had the highest tendency to fouling, while the tested sample of spring water has the lowest tendency to fouling. The tested tap waters had a slight tendency to fouling, and low-mineralized water had almost twice the tendency to form deposits. Contamination of tap water with hydrocarbon fraction did not significantly affect the amount of deposits generated on the exchanger. However, acidification of the low-mineralized water sample resulted in a decrease in the mass of sediments on the exchanger due to corrosion. Based

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on microscopic and infrared analyses, it was found that the deposits generated by the water samples on the exchangers are mainly carbonate in nature. Additionally, in the case of an acidified water sample, corrosion products appeared in the deposit, and in the case of water contaminated with a hydrocarbon fraction, hydrocarbons were also deposited on the exchanger in addition to carbonates.

The developed methodology using the FALEX apparatus allows for the assessment of the fouling tendency of process waters and enables their differentiation in terms of contamination of heat exchangers with deposits. The use of the developed methodology for assessing fouling in process waters in preliminary tests on a laboratory scale will reduce the risk of fouling on an industrial scale.

Competitive catalysts for hydrogen-rich gas production via co-pyrolysis of lignocellulosic biomass and plastic

Jacek Grams[1],*, Marcin Jędrzejczyk[1], Joanna Gosciańska[2]

Keywords: co-pyrolysis, hydrogen, biomass, polymer waste, nickel catalyst

ABSTRACT

The use of hydrogen as a substrate for various industrial processes and as an energy carrier has been gaining more and more attention in recent years. It can be not only produced by natural gas reforming but also using renewable resources, such as lignocellulosic biomass. Thermochemical conversion of this type of feedstock is considered to be one of the most promising methods allowing the production of H_2-rich gas. Unfortunately, the efficiency of this process is still not satisfactory. Therefore, researchers are undertaking efforts to increase the hydrogen yield by the application of heterogeneous catalysts [1]. Taking that into account we decided to develop competitive Ni-based catalysts for the upgrading of preliminary products coming from thermal conversion of lignocellulosic feedstock. Instead of using only biomass, we applied a mixture of biomass and waste plastic, which allowed not only to boost hydrogen production but also to get rid of another type of very popular and harmful waste [2].

It is known that the catalytic performance of Ni nanoparticles strongly depends on the type of the used support, which can affect the stability and coking resistance of the synthesized catalysts. That is why this work was focused on the selection, synthesis, and characterization of the most advantageous materials, which could act as nickel support in hydrogen-rich gas production via co-pyrolysis of the mixture of lignocellulosic biomass and waste plastic. Metal oxides, zeolites, and silica-based minerals have been used for this purpose. The reaction was performed in a two-step reactor with separate feedstock and catalyst beds. Cellulose, various biomass samples, and polyethylene were processed. The obtained products were determined using gas chromatography. The synthesized catalysts were subjected to the comprehensive characterization of their physicochemical properties with the use of TPR, TPD-NH_3, TPD-CO_2, XRD, TEM, ToF-SIMS, FTIR, and TG, among others.

The obtained results demonstrated that the presence of Ni catalysts allowed for a sustainable increase in the amount of formed hydrogen during high-temperature treatment of lignocellulosic biomass. An introduction of polyethylene to the reaction mixture additionally enhanced the efficiency of hydrogen-rich gas production, which was ascribed to the synergy effect observed during the simultaneous decomposition of both polyethylene and lignocellulose [3]. The beneficial effect of the application of a catalyst was attributed to its ability to promote the cracking of primary pyrolysis products and their further steam and dry reforming or gasification. This resulted in the substantial increase in the selectivity of hydrogen formation and its contribution in the mixture of gaseous products.

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The volatility of some ecotoxic elements during combustion of various wastewater sludge

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Keywords: wastewater sludge, ecotoxic elements, heavy metals, sludge combustion

ABSTRACT

Proper disposal of wastewater sludge is a growing challenge due to rising environmental standards. For this reason, the share of thermal utilization among the methods of managing this waste is increasing every year [1, 2]. However, there is a risk of ecotoxic elements being released during incineration, which can cause negative effects on human health and the environment. The current emission standards for these pollutants from waste incineration processes [3] make the need for awareness of the factors affecting their volatility and potential emission into the atmosphere.

In order to perform a preliminary analysis of the distribution of ecotoxic elements such as lead Pb, zinc Zn and chromium Cr, laboratory tests were carried out to analyse the content of these elements in the combustion products, i.e. in the flue gas and in the solid residue. The sludge combustion process was carried out in a horizontal tube furnace at a temperature 1000°C and an air flow 0.8-0.85 dm^3/min. Analysis of the elements content in the flue gas was performed in accordance with modified US EPA Method 29 [4]. The content of Pb, Zn and Cr in all products was determined by atomic absorption spectrometry. The study was conducted for five different sludges from industrial wastewater treatment plants, processing wastewater from: animal fat production (AFP), vegetable and fruit processing with an additional stream from dairy processing and municipal sewage (FPM), food production (FP), refinery (REF) and coke plant (CP). The characterization of the investigated sludges is summarized in the database [5]. In order to investigate potential feedstock factors affecting the volatility of the considered elements, the correlations of the amount of a particular element passing into the flue gas with their initial content in the sludge, their form of occurrence and the amount of associated components such as sulfur S and chlorine Cl were analyzed. The sulfur content was determined by an instrumental method according to ISO 21663, while the chlorine content was determined according to EN 15408. The form of Pb, Zn and Cr occurrence was determined based on the BCR (European Community Bureau of Reference) sequential extraction method [6]. The examined sludges differed significantly in chemical composition as well as in the content of the considered elements and their form of occurrence.

The results showed that during sludge combustion process, the considered elements remain mostly in the ash. However, there have been cases of significant release of Pb and Zn (more than 20% has passed into the flue gas). Moreover, it was observed that the volatility of the considered elements differed significantly both between them and between the combusted sludges. The greatest differences were observed in the case of Pb, which passed into the gas in amounts ranging from 0.3% to as much as 67%, in order FP<FPM<AFP<REF<CP. The volatility of Zn in the combustion of the tested sludges also varied, with 0.1% to almost 20% passing into the flue gas, in the same order as for Pb. The least variation in volatility was observed for Cr, which was released into gaseous form at a rate of 0.9-14%, in order FP<FPM<APF<CP<REF.

Based on the correlation analysis, it can be preliminarily concluded that the amount of Pb released into the flue gas was most affected by the sulfur content in the sludge and

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the associated form of lead occurrence - the organic fraction (F3) called oxidation fraction, which is also associated with sulfur compounds due to sulfide oxidation. A significant correlation between Zn in the flue gas and sulfur content in the sludge was also noted, as well as a significant correlation with its residual form (F4) associated with minerals. In the case of Cr, no significant correlations between its volatility and the considered associated components or its form of occurrence were found on the basis of the conducted research.

It should be pointed out that the volatility of ecotoxic elements in the process of wastewater sludge combustion is affected not only by feedstock factors but mainly by technological parameters such as the type of combustor, combustion temperature, air ratio etc. [7]. Therefore, the presented research is only a preliminary step indicating significant differences in the behavior of Pb, Zn and Cr in the combustion processes of wastewater sludge of different origins.

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Enhancing Oxygen Evolution Reaction efficiency - plasma treatment of carbon supports for cobalt-based electrochemical catalysts

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Keywords: hydrogen, oxygen evolution reaction, carbon, cobalt, plasma

ABSTRACT

The global need for clean energy pushes researchers and industries to seek eco-friendly alternatives to fossil fuels. [1] Hydrogen, as a green and sustainable energy carrier, can be produced by electrochemical water splitting. However, the efficiency of this process is hampered by the oxygen evolution reaction (OER), necessitating electrocatalysts to enhance efficiency. Current electrocatalysts, such as ruthenium and iridium, are costly and scarce. [2] Carbon-based materials are widely researched for their electrocatalytic potential. However, they often lack strong interaction with the active phase. Therefore, oxidative treatment is frequently employed to increase the number of anchoring sites. [3]

This research aimed to develop an electrocatalyst of the OER process based on two different type of carbon supports; mesoporous carbon and biochars with cobalt active phase. The main goal of the study was to investigate the influence of plasma pretreatment and active phase method deposition on cobalt dispersion and catalyst activity in OER process. Graphitic mesoporous carbons, synthesized using a hard-template method from KIT-6 silica with sucrose and aniline as carbon precursors were subjected to modification with oxygen plasma and incorporation of cobalt via a sonochemical deposition procedure. Biochars (carbonized triticale straw, sunflower hulls, pine sawdust, walnut shells, and sewage sludge) underwent treatment with air plasma, followed by the introduction of cobalt active phase through a deposition-precipitation method.

According to XPS analysis, plasma treatment of mesoporous carbon and well-carbonized biochars increases the number of surface oxygen groups. On the other hand, treating with plasma supports based on sunflower husks and sewage sludge, which are more poorly-carbonized, leads to a decrease in oxygen content but an increase in COO-type groups fraction while increasing the degree of carbonization. Electrochemical activity in the oxygen evolution reaction was determined for reference carbon supports and Co-doped carbons with and without plasma treatment. Except for one sample, plasma treatment before cobalt deposition resulted in increased reactivity, lowering overpotential value. The best catalytic materials among mesoporous carbon proved to be composites containing both a high amount of active phase and a high content of heteroatoms in the carbon structure with $\eta=360$ mV. In the case of biochar's supports the most active materials was based on triticale straw treated with plasma with $\eta=358$ mV.

This work demonstrates the importance of proper carbon surface functionalization, which has an impact on active phase dispersion and finally on the activity. The activity and stability of materials based on biochars are comparable with composite catalysts based on mesoporous carbons, which shows that active catalys can be obtain using simple method and finding applications for materials considered as waste, thereby aligning with the principles of sustainable development.

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Examinations of catalytic waste tire char gasification directed towards obtaining hydrogen-rich gas

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Keywords: hydrogen-rich gas, gasification, catalysts, waste management

ABSTRACT

The development of the automotive industry and the growing number of various vehicles generate demand for the global production of tires, which translates into an increasing amount of waste tires generated. One of the most promising and dynamically developed ways of managing waste tires is the pyrolysis process resulting in valuable products (oil, gas, and char). Tire char is considered valuable residue, however challenging to manage due to low reactivity. Catalytic gasification seems to be an up-and-coming solution to this problem; however, requiring cheap and efficient catalysts as well as appropriate process conditions to ensure efficient feedstock conversion and direct the process towards the formation of gas with the desired composition, i.e. H_2-rich gas. Biomass ash as a waste with a high content of catalytically active compounds (including those showing selectivity towards hydrogen formation) seems to be a suitable catalytic additive for the gasification of tire char. Therefore, the work aimed to assess the impact of two different biomass ashes as catalysts in the gasification of a low-reactive, but caloric product of tire pyrolysis - char. Beech chip ash and corn cob ash were selected for research since both contained the same catalytically active compounds (mainly K and Ca compounds) but in different proportions. Tire-char and biomass ashes were characterized, physically mixed (amount of catalyst: 0, 5, 10 wt.%), and gasified using the thermovolumetric method based on an analysis of the resulting gas. Gasification measurements were carried out in the atmosphere of steam under isothermal conditions in the temperature range of 800-850℃ and pressure of 0.5-1MPa. The measurements allowed us to determine the formation rates of the main gas components (H_2, CO, CO_2, and CH_4). Based on that, the reactivity of samples, quality, and quantity of the resulting gas, and kinetic parameters (activation energy and pre-exponential factor) of the process were assessed. As a result, the influence of the type and amount of catalyst on tire-char gasification were evaluated, and the optimal process conditions were determined to ensure an efficient process and the production of hydrogen-rich gas. Moreover, valuable information regarding the composition of catalysts with high activity was provided.

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Assessment of the degree of reduction of eutrophication potential on the basis of physicochemical tests performed on municipal wastewater from the Płaszów Wastewater Treatment Plant

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Keywords: biogenic elements, eutrophication, wastewater treatment

ABSTRACT

Over the centuries, eutrophication has been a slow phenomenon. However, over the years, its pace and scope have changed and have been greatly increased as a result of human activity. Eutrophication, both natural and cultural, eventually leads to the degradation of water bodies. However, in the case of a natural phenomenon, the growth of biomass is gradual and can last from hundreds to even thousands of years without disturbing the natural balance of aquatic ecosystems. The process of anthropopressure, which lasts several to several decades, often quickly results in harmful ecological consequences. One of the most visible and characteristic effects of anthropogenic eutrophication is dense phytoplankton blooms. The resulting blooms deteriorate the properties of the water - they negatively affect its smell, taste, and reduce its clarity, which in turn significantly reduces the quality of the water. Flowering algae limit the access of light to the deeper layers of water, leading to the death of some submerged plant species and implies changes in plant species diversity. Eutrophication is also associated with a high rate of photosynthesis and the oxygen saturation of the water characteristic of it. As a result, the pH in the body of water changes rapidly, which can reach extreme levels during the day. Another problem is algae death. This phenomenon is accompanied by drastic changes in the oxygen conditions that prevail in the aquatic environment. This results in the formation of "dead zones", characterized by a lack of sufficient oxygen needed for the life of most organisms, resulting in a decrease in the number of aquatic animals. A very dangerous effect of eutrophication on the aquatic environment is also algae blooms, which produce harmful toxins. Cyanobacteria, commonly referred to as cyanobacteria, are a special genus. Cyanobacteria produce a range of toxic substances, such as neurotoxins and hepatoxins, which are harmful to animal and human health.

In the context of preventing the development of eutrophication, wastewater treatment plants play an important role, reducing the nutrient load in wastewater before it is discharged into water bodies. For this reason, the analysis of the composition of urban wastewater is an important topic of scientific research, necessary to ensure an effective and efficient treatment process.

In this study, selected physicochemical parameters of municipal wastewater from the Płaszów Wastewater Treatment Plant were analyzed. The research part focused on the analysis of bioavailable forms of nitrogen and phosphorus in wastewater. In addition, the physicochemical properties of raw and biologically treated wastewater were compared, the change in the selected properties was investigated, and the effectiveness of the wastewater treatment system in Płaszów was evaluated. Parameters analysed were: pH, total suspended solids, BOD_5, COD, ammonium nitrogen, nitrate(III) nitrogen, nitrate nitrogen(V), total Kjedahl nitrogen, total nitrogen, orthophosphates, total phosphorus.

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Investigation of metal content in soils by means of mass spectrometry with ionization in the inductively coupled plasma ICP-MS and estimation of the uncertainty of the analytical process

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Keywords: soil pollution, mass spectrometry ICP-MS, estimation of the uncertainty of the analytical process,

ABSTRACT

Soil, as a basic and extremely important element of the environment, is a source of vegetation development, which is the basis of the trophic chain, without which life on Earth would not function. The composition of soils and the content of the most important chemical compounds in soils depends on many factors, and even relatively small amounts of pollutants can cause disturbance in the development of microorganisms and vegetation forming the biocenosis. The practice of improper use of fertilizers and chemicals for various purposes has a direct impact on the biochemical composition of soils. Micronutrients play an important role in the process of growth and proper development of crops, but the use of agrochemicals in excess can be a negative factor affecting the quality of developed land. The accumulation of conditioners in the soil can lead to salinization of the soil. For this reason, the rational use of the chemical industry to improve the quality of crops should take into account the impact on human health and the natural environment. It also happens that in cases of significant interference, land is devastated. In such extreme circumstances, there is a complete and permanent loss of soil usability, and in the long run, its devastation. In order to maintain an optimal environmental condition, it is crucial to carry out periodic inspections of the composition of soils in terms of the content of substances that threaten its quality. The essence of properly conducted analyses is the proper selection of the test method and the validation of the apparatus in order to determine the usefulness of the technique used to determine the selected soil components.

The research was based on the analysis of the content of elements considered harmful in soil samples from agricultural areas collected in Baranówka and Głogoczów, as well as from the urban area - a green area located on the premises of the Oil and Gas Institute in Krakow. Specially prepared samples were mineralized for analysis by ICP-MS inductively coupled plasma mass spectrometry. The content of heavy metals was determined and the condition of the soil was assessed on the basis of - guidelines listed in the paper - contained in the Polish and European legislation. On the basis of the results of the uncertainty estimation using the ROBAN program, the equipment used for the tests was validated, and the accuracy of the sampling method and process used was evaluated.

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Fine-tuned ruthenium catalyst for synthesis of biomass derived furanic - type biofuels

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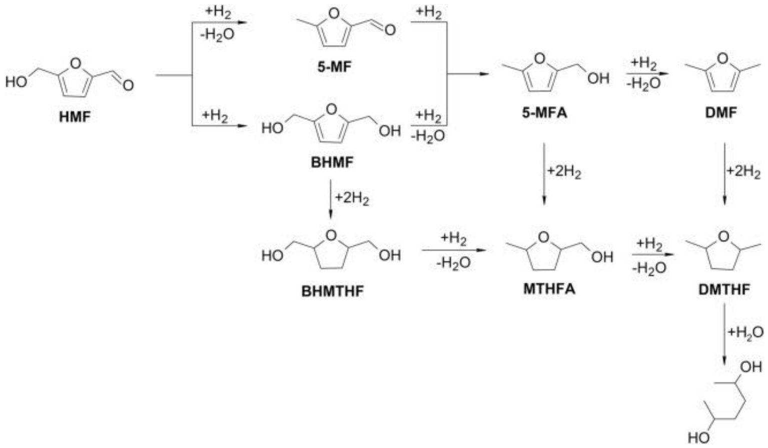
Keywords: biofuel, hydrogenation, biomass, heterogeneous catalysts

ABSTRACT

5-hydroxymethylfurfural (HMF) derived from the lignocellulosic biomass feedstock is considered as a versatile platform molecule that can be converted into a wide span of desirable chemicals with the high energetic value. Among them, 2,5-dimethylfuran (DMF) and 2,5-dimethyltetrahydrofuran (DMTHF) are pivotal molecules with applications as biofuels or biofuel additives [1].

One of the most efficient metals in the hydrogenation and hydrogenolysis of many biomass-derived oxygenates is ruthenium, mainly owing to its outstanding performance that rely on the decrease of the energetic span of the reaction pathway in the presence of a protic solvent. It's very high activity is however an obstacle for obtaining high selectivity, as it is a challenge to tune its properties to avoid overhydrogenation reactions or other secondary reactions.



Scheme 1. Hydroxymetylfurfural hydrogenation

Modification of Ru by interaction with the support or by second metal allows to tune the selectivity towards molecules of choice. Additionally, thanks to the synthesis modification by photodeposition method (time of irradiation) we were able to prepare materials having a Ru nanoparticle within the range 0.6-4.9 nm. We observed that the size of Ru particles is one of the key parameters strongly influencing the activity and selectivity in the investigated reaction. At low reaction temperature (120°C) selective hydrogenation of the C=C bonds in BHMF allow to form bis(hydroxymethyl) tetrahydrofuran (BHMTHF) (valuable monomers in the polymer industry) in the very high yield (99,5%) with Ru

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catalyst possessing particle size 1.8 nm. However, DMF which was favored at high reaction temperatures (180°C, 15bar of H_2) could be reached with the maximum yield of 60% due to the over hydrogenation reaction and formation of DMTHF despite the Ru particle size. Modification of Ru by Ni allow to control the reaction performance towards DMF. We evidenced that the increase of the Ni/Ru bulk ratio favored the HMF conversion, that reached 100% for a Ni/Ru molar ratio of 1.5. By contrast, the DMF selectivity pattern exhibited a volcano-like shape, with a maximum selectivity of 96% being achieved for a Ni/Ru molar ratio of 1.0. Thanks to this novel sustainable method of catalysts preparation, highly selective and stable Ru-Ni materials have been developed, with an activity that can be easily optimized through the tuning of the Ru:Ni ratio.

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A-site defect modulation in perovskites for designing high-performance nanofiber electrodes with *in situ* exsolution of nanoparticles for symmetrical SOFCs

Michał Gogacz[1], **Kun Zheng**[1,2,*], **Jakub Lach**[1], **Jakub Skiba**[1]

Keywords: SOFC, defect modulation, perovskite electrode, nanofibers, *in situ* exsolution

ABSTRACT

Solid oxide fuel cells (SOFCs) hold the promise as a technology for energy conversion and storage, potentially playing a vital role in sustainable development efforts by significantly boosting the use of clean energy. When renewable energy sources produce surplus energy, SOFCs can generate hydrogen through electrolysis, which can then be used later to produce electricity and heat as needed. Symmetrical solid oxide fuel cells offer various advantages such as simplified production and lower costs due to using the same material in both anode and cathode electrodes. They also exhibit improved compatibility and can resist certain degradation mechanisms by swapping electrode roles. However, challenges remain, including the need to find materials suitable for both reducing and oxidizing atmospheres while maintaining excellent electrochemical performance. However, the typical high operating temperature of symmetrical SOFCs, exceeding 800 °C, poses challenges such as thermal compatibility issues and material degradation, leading to increased costs and rendering SOFCs economically unviable [1]. At lower desired operating temperatures below 600 °C, most electrode materials lose their electrochemical efficiency, causing a drastic drop in SOFC performance. Thus, developing new, highly efficient electrodes that can operate at lower temperatures is crucial for the economical and high-performance advancement of symmetrical SOFCs. Recently, there has been a surge in interest of heterostructured electrode materials created using various techniques, including mechanical milling, infiltration, *in situ* assembling, and *in situ* exsolution of nanoparticles. These heterostructured electrodes offer distinct advantages, such as high mixed ionic-electronic conductivity (MIEC) and enhanced catalytic activities. One technique for obtaining heterostructured materials is *in situ* exsolution of nanoparticles. In recent years, research on these materials has been gaining popularity because through this process it is possible to create stable and well-dispersed metal nanoparticles anchored on the electrode surface, which increases the specific surface and catalytic activities of the electrode resulting in an significant increase of the cell's performance and additionally extending the lifespan [2].The exsolution process from perovskite oxide involves a number of reaction steps, including cation diffusion, reduction, particle nucleation and grain growth. After the migration of metal particles from inside the material structure to its surface, metal cations become surface segregated and reduced to the metallic state (M^{n+} to M_0), then they begin to nucleate and grow, forming metal nanoparticles. A popular group of materials studied in this field are perovskite oxide (ABO_3) structure materials and derivatives. However, exsolution phenomenon from stoichiometric perovskites (A/B = 1) is usually marginal and only a limited number of metal cations from the B sublattice can be exsolved, even if the process is conducted at high temperature. Therefore, several techniques have been developed to improve the exsolution process e.g. A-site deficiency, phase transformation, external experimental conditions [3, 4].

In this work, A-site defect engineered $Sr_{2-x}Fe_{1.4}Ti_{0.2}M_{0.2}Ni_{0.1}Co_{0.1}O_{6-\delta}$ (x= 2-1.8; M =

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Cr, Mn, Mo, W) perovskites have been studied as electrode materials for symmetrical SOFCs. It has been found that the introduction of A-site deficiency in perovskites significantly improves the electrochemical performance of the electrode performance, especially in air condition. During the reduction process of materials, phase transition from simple perovskite to Ruddlesden-Popper was observed, which significantly promotes the *in situ* exsolution of nanoparticles, resulting in excellent electrochemical performance of the electrodes in anode condition. To further enhance the performance, the electrode morphology has been modified using electrospinning techniques to obtain nanofibers, contributing to a notable enhancement of efficiency, especially at the intermediate temperature range (≤700 °C).

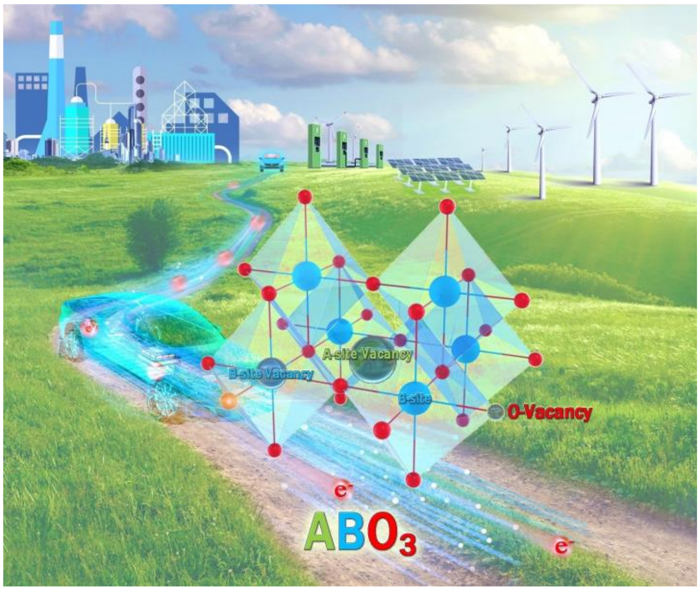

Figure 1. Vacancies Modulation in the ABO$_3$ Perovskites for Catalytic Applications [5].

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ENERGY FUELS ENVIRONMENT EFE2024
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Design of efficient and durable symmetrical protonic ceramic fuel cells at intermediate temperatures via B-site doping of Ni in $BaCe_{0.56}Zr_{0.2}Ni_{0.04}Y_{0.2}O_{3-\delta}$

Amir Sultan[1], **Muhammad Bilal Hanif** [2,*], **Kun Zheng** [3, 4*]

Keywords: Solid oxide fuel cell, Protonic conductivity, Sintering temperature, Electrolyte, Electrochemical impedance spectroscopy

ABSTRACT

Protonic ceramic fuel cells (PCFCs), which feature solid oxide fuel cells (SOFCs) with solid proton-conducting electrolyte materials, offer a viable alternative to conventional SOFCs at lower temperatures. Conventional materials that transport oxygen ions and work at high temperatures between 800 and 1000 °C are typically utilized as the electrolytes in SOFCs. The degradation that occurs at these temperatures and the difficulty of sealing ceramic, glass, and metal parts at high temperatures are the main hurdles that currently restrict the commercialization of this technology. Higher working temperatures demand a significant energy input and a protracted startup period. As a result, there is a requirement for materials that operate effectively at intermediate-to-low temperatures (IT; 450–700 °C). For electrolyte materials working in the IT range, PCFC materials are preferable because of the low activation energy of their conductivity [1].

The $BaCe_{0.5}Zr_{0.3}Y_{0.2}O_{3-\delta}$ (BCZY) has been investigated extensively due to its good stability and high protonic conductivity [2]. However, the sintering temperature of BCZY is above 1600 °C to achieve the required densification [3]. High sintering temperature leads to evaporation of barium and the subsequent segregation of doped elements [4]. In this study, a B–site doped $BaCe_{0.56}Zr_{0.2}Ni_{0.04}Y_{0.2}O_{3-\delta}$ (BCZNY) electrolyte was fabricated to address this drawback. The impact of Ni addition on sintering and electrical properties was examined. By adding Ni to the B–site of BCZY, a substantial decrease in the sintering temperature was achieved, i.e., from 1600 °C (for BCZY) to 1300 °C (for BCZNY). A conductivity value of 0.05 S cm^{-1} at 700 °C was observed for BCZNY electrolyte in a moist nitrogen environment. In addition, $SrFe_{0.8}Mo_{0.2}O_{3-\delta}$ (SFM) is utilized as a symmetrical electrode material due to its high ionic and electronic conductivity. SFM electrode was synthesized via combustion process and exhibited suitable chemical and thermal compatibility with BCZY and BCZNY electrolytes up to 1100 °C. A single–phase cubic structure along with the surface morphology of electrolyte–supported symmetrical cells was confirmed by X-ray diffraction and scanning electron microscopy. Electrochemical impedance spectroscopy was conducted to identify the area–specific polarization resistance (ASR). The lowest ASR values of 0.037, 0.081, and 0.327 Ω cm^2 at 800, 700, and 600 °C in humidified hydrogen were obtained in the SFM-BCZNY composite electrode. The symmetrical cell achieved a peak power density of 254 m W cm^{-2} (cell configuration; SFM-BCZNY | BCZNY | SFM-BCZNY) at 800 °C. The fuel cell devices showed long–term stability of the fuel cell device for 100 h at 700 °C under a current of 120 mA cm^{-2}.

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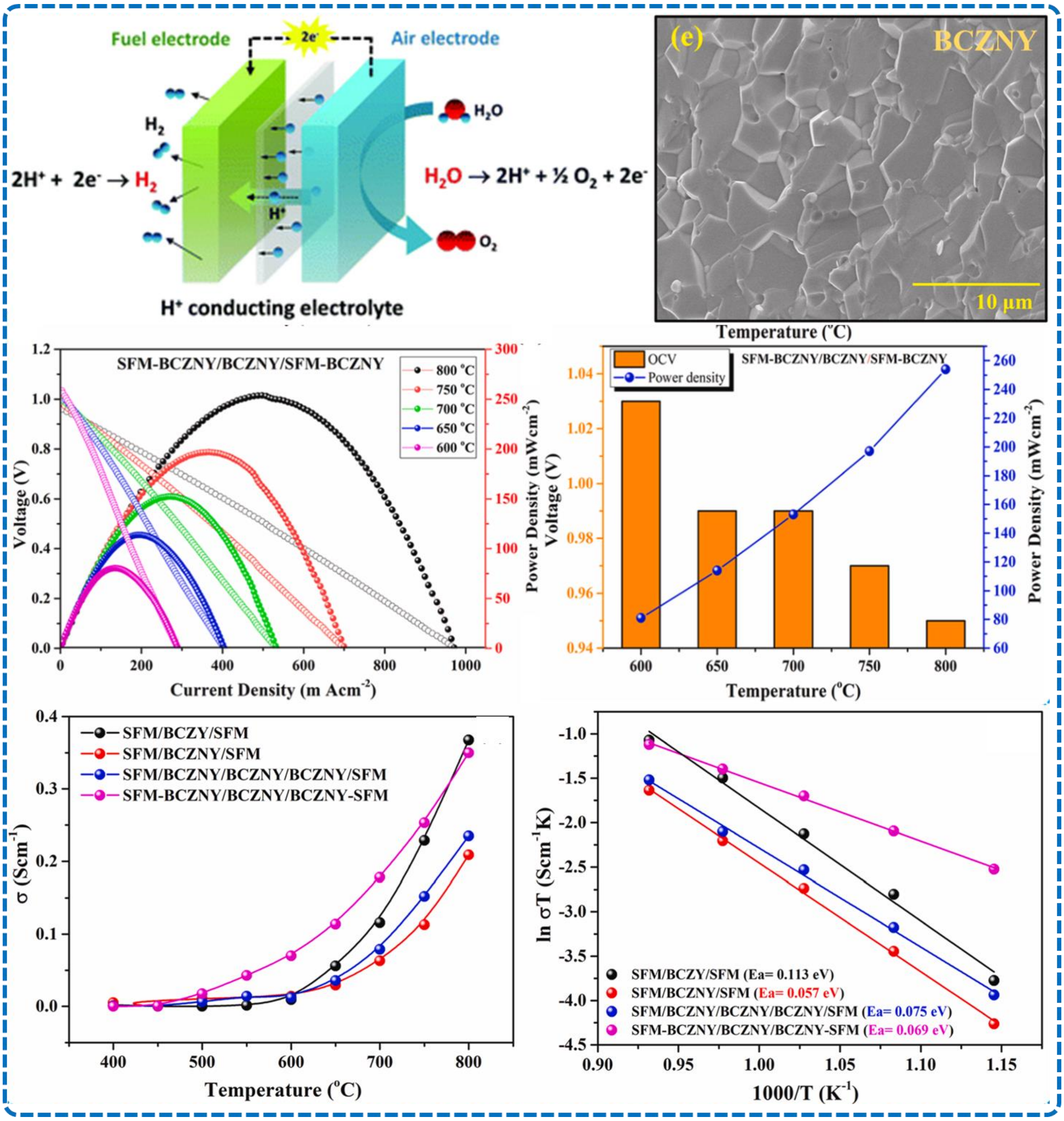
Considering the presented results, the as-prepared BCZNY is a promising protonic electrolyte for IT-SOFCs.



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Acknowledgement: The work is funded by the research project supported by the program „Excellence Initiative – Research University" for the AGH University of Krakow.

Assessment of the possibility of upgrading waste biomass derived from tree leaves and needles in the washing process

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Keywords: waste biomass, fallen leaves, washing, ash, mercury

ABSTRACT

The use of waste biomass for power generation is becoming increasingly important. This contributes to the decrease in fossil fuel consumption and the reduction in greenhouse gas emissions. Waste biomass is of relatively low quality and is characterized by a high ash and mercury content as well as a low calorific value. The upgrading of waste biomass can be obtained using the washing process. Waste biomass of plant origin in the form of tree leaves and needles could potentially be used for this purpose.

Horse chestnut (*Aesculus hippocastanum*) and Norway maple (*Acer platanoides*) leaves as well as European larch needles (*Larix decidua*) were collected. Samples were collected monthly from May to October. For the first five months, the samples were collected from tree branches, and in the last month, the samples were collected from the ground (fallen leaves). The bulk sample was divided into two parts. The first part was washed to remove dust deposited on the surface of leaves and needles. All samples were then air-pre-dried to remove surface moisture and ground using a knife mill to obtain a grain size of less than 1.0 mm. For all samples (raw and washed biomass), the content of moisture, ash, and mercury was determined.

The mercury content in the leaves and needles of the examined tree species was significantly correlated with the ash content. Although this relationship was found for each tree species (Figure 1), a lack of correlation was observed for the entire sample population. The mercury and ash content increased with the lifetime of the leaves and needles, suggesting that significant amounts of mercury are captured together with particulate matter from the air. Assessment of the effectiveness of the washing process in upgrading waste biomass was carried out for samples collected in October (fallen leaves). The washing process allowed a significant reduction in both ash (from 0.5 to 1.0 pp. on a dry basis) and mercury content (from 9 to 11 µgHg/kg on a dry basis). This represents a relative decrease from 5 to 11% and from 17 to 18% for the ash and mercury content, respectively. Further upgrading of biomass would require the use of a torrefaction process.

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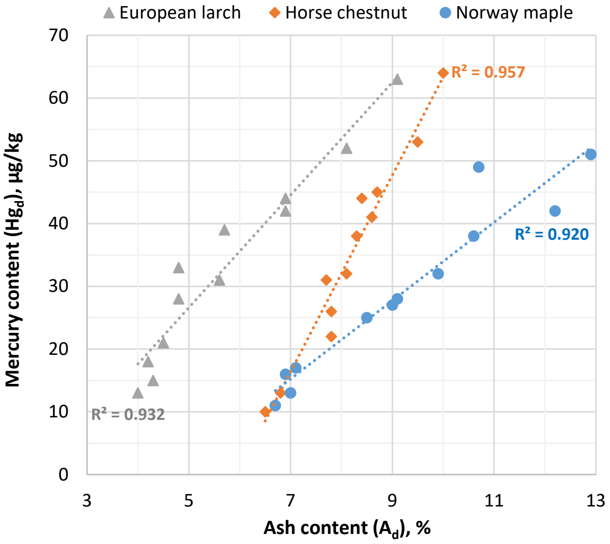

Figure 1. Relationship between mercury content and ash content for tree species examined

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Measurements of tritium in water using electrolytic enrichment and liquid scintillation counting spectrometer

Joanna Najman*[1], Sylwia Błażej[1], Jerzy W. Mietelski[1], Agata Walencik-Łata[2], Beata Kozłowska[2], Ryszard Misiak[1], Mirosław Bartyzel[1], Bogdan Wąs[1]

Keywords: tritium, electrolitycal enrichment, LSC spectrometer

ABSTRACT

Tritium is produced in the atmosphere by cosmic radiation interaction with nitrogen [1]. It decays to ^{3}He with a half-life of 4500.9±8 days [2]. Tritium is also produced in nuclear weapons tests and in nuclear power reactors. Atmospheric tritium reacts to form tritiated water: HTO and enters the natural water cycle.

The "Poland's Energy Policy until 2040 (PEP2040)" project envisions initiating the first unit (with a capacity ranging from approximately 1 to 1.6 GW) of the inaugural nuclear power plant by 2033. Subsequent units are planned for launch every 2 to 3 years, with the entire nuclear program aiming for the completion of 6 units by 2043 [3]. Thus, it is crucial to monitor levels of radioactive contamination.

The method of tritium measurements in water using electrolytic enrichment and liquid scintillation counting was developed in the Institute of Nuclear Physics PAN. The setup consists of four electrolytic cells which can run simultaneously with a power supply that allows the cells system to be powered with a voltage of up to 25 volts and a current of up to 5 A. During our experiment, the initial sample volume stood at 100 ml, but ultimately dwindled to approximately 7 ml. To safeguard against sample evaporation during electrolysis, we meticulously upheld the temperature within the range of 0 to 4 degrees Celsius, employing an electrical refrigerator. The electrolytic enrichment procedure spanned about 9 days. Following this, the resultant 5 ml sample was amalgamated with 15 ml of LSC cocktail Ultima Gold LLT. Tritium measurements were performed using the Tri-Carb 5110TR LSC spectrometer in the Laboratory of Low Activities, Institute of Physics, University of Silesia in Katowice. The method's calibration involved employing an external standard with a tritium activity concentration set at 142 Bq/g ± 3 Bq/g on June 11, 2019. We attained a detection efficiency of 44%, an enrichment factor of approximately 9, and established a detection limit of 1.1 Bq/kg after 120 minutes of counting. The technique underwent further examination utilizing two water standards sourced from the Almera Intercalibration 2023 [4] and ICHTJ Intercalibration initiatives. The computations were carried out employing the formula outlined by Al Mamun [5].

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Possibility of reducing mercury and carbon dioxide emissions through the use of char produced derived from municipal solid waste

Marcelina Bury[1,]*, Tadeusz Dziok[1], Piotr Burmistrz[2]

Keywords: mercury, waste, thermal treatment, mercury emission, carbon dioxide emission

ABSTRACT

The increasing world population contributes to the growth of waste generation and a significant increase in energy demand. Therefore, coal will be increasingly replaced by alternative fuels produced from solid municipal waste. The use of such fuel causes many difficulties due to its heterogeneity and high mercury content. For the use of alternative fuels, the content of biodegradable fractions is crucial. The energy generated from biodegradable fractions is classified as generated from renewable sources. The content of biodegradable fractions will depend on the type of waste. The reduction of carbon dioxide emissions resulting from replacing coal with alternative fuel derived from waste depends on the content of biodegradable fractions. In the case of mercury emission, the content of mercury in wastes can be reduced in the be low-temperature pyrolysis.

The aim of the research was to assess the potential for reducing mercury and carbon dioxide emissions through the implementation of low-temperature waste pyrolysis. The research was conducted using samples of paper waste, cardboard, textiles, plastics, foil, and rubber. Additionally, samples of RDF (refuse derived fuel) produced from municipal solid waste, as well as sewage sludge from municipal wastewater treatment plants, were subjected to analysis. The low-temperature pyrolysis was carried out at a temperature of 300°C, with the residence time of 30 minutes, and an argon flow rate of 500 cm^3/min.

The low-temperature pyrolysis process at 300°C allowed for a significant reduction in mercury content regardless of the type of waste analyzed. In the case of samples RDF and sewage sludge, it was possible to change the classification of the fuel from SRF classes 2 and 3 to SRF class 1 regarding mercury content. The low mercury content in the char will result in relatively low mercury concentrations in the flue gases. Chars produced from the particular type of waste were characterized by a high content of biodegradable fractions (besides the rubber and plastic samples). The carbon dioxide emission factors determined for non-biodegradable fractions were much more lower than for coal, ranging from 47% (textiles and RDF) to 90% (sewage sludge). For the rubber and plastic samples, the carbon dioxide emission factor was lower than for coal by 13% on average.

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Sustainable Energy Solutions: Electrochromic Innovations

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Keywords: Sustainable Development Goals, sol-gel process, organic-inorganic hybrids, ionic liquids, electrochromic devices

ABSTRACT

Aligned with the United Nations' Sustainable Development Goals for 2030, our study contributes to enhancing energy efficiency and fostering sustainable cities via the application of electrochromic technologies [1]. Electrochromic devices (ECDs) display a reversible color shift when a minimal voltage (1-3 V) is applied. Archetypal devices are composed of multiple layers: a cathodically coloring film of tungsten trioxide (WO_3), an electrolyte layer, an anodically coloring nickel oxide (NiO) film, and two transparent conductive oxide layers [2].

Our research is centered on developing di-urea [3] cross-linked polypropylene-siloxane hybrids through the sol-gel process, into which different ionic liquids are incorporated. This eco-friendly and economical approach is acknowledged for generating uniform and stable materials suitable for solid-state electrochemical uses [4]. The properties of these materials are finely tuned by managing the organic and inorganic constituents, solvent type, reaction conditions, and additional compounds. The sol-gel products are characterized by excellent conductivity, thermal resilience, and non-volatility.

We employed several techniques like Fourier-transform infrared spectroscopy, X-ray diffraction, confocal Raman microscopy, thermogravimetric analysis, polarized optical microscopy, atomic force microscopy, and contact angle measurements, to assess the structure, morphology, thermal stability, and wettability of the xerogel films. Optimized hybrids were utilized as ormolytes in ECDs, and their electro-optical performance was evaluated using chronoamperometry, cyclic voltammetry, and spectroscopy in the visible and near-infrared ranges, alongside color coordinate assessments.

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Bio-coke for ferroalloys production process

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Keywords: bio-coke, biomass, coke quality, ferroalloys, biocarbon

ABSTRACT

Coke is used in a variety of crucial industrial processes besides the production of steel such as the foundry industry, insulating wool, quicklime, carbide production, fuel for heating and ferroalloys production. In addition to its chemical role - reductant, carburizer - it also has a physical function - a gas-permeable grate supporting the column of charge materials, ensuring proper flow of gases and flow of liquid products to the lower parts of the furnace. It also acts as a fuel - a source of heat energy for the process. In general, the role it plays depends on the process in which it is used. Due to the fact that coke is produced from fossil fuels - coking coals - its use is associated with the emission of carbon dioxide - a greenhouse gas contributing to global warming. One of the methods of reducing carbon dioxide emissions from the above-mentioned processes would be the use of bio-coke - a hybrid reductant based on coking coal and raw materials of biomass origin, which would act as a supplier of renewable elemental carbon which is considered as carbon neutral.

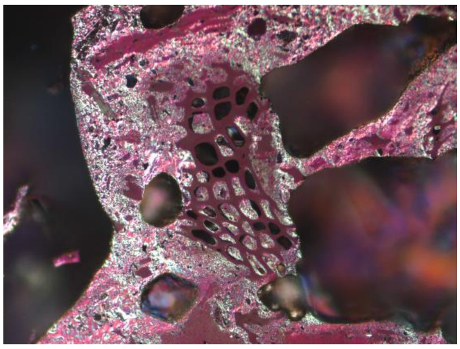

Figure 1. Bio-coke texture under the optical microscopy (polarised light)

The presentation shows selected results of the properties of bio-coke in relation to its structure, texture and technological properties. The bio-coke production process has been verified on a pilot scale. On a pilot scale, the use of bio-coke for carbothermal reduction of manganese ores to produce ferromanganese was also verified.

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Hybrid energy sources using hydrogen and fuel cells in mobile robotics

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Keywords: robots, hydrogen, fuel cell, hybrid power source

ABSTRACT

Currently, manufactured unmanned ground vehicles weighing up to one tonne are frequently equipped with electric drive units. Electric drive unit design solutions are highly efficient, operate quietly and do not emit substances harmful to the environment. A wide selection of electric traction motors, along with suitable gearboxes and on-board power electronics, makes it possible to build robots with desirable performance characteristics, such as extended range and operating time, which allows for new civilian and specialised applications.

The use of appropriate electrical energy storage is one of the main factors determining the reliability of the missions performed by mobile robots. The role of the electrical energy storage tank is to supply the drive unit with electrical energy as required by the electrical load profile. It also provides the energy necessary to power equipment such as control and measuring devices, monitoring devices and diagnostic sensors used during the mission and on-board high performance embedded computing systems.

This study presents a description of the feasibility of using electrochemical energy sources such as electrochemical batteries, fuel cells and supercapacitors to power the drive unit and on-board devices used in mobile robots. It also discusses the results of research on the viability of using 200W up to 5kW hydrogen–oxygen fuel cells as components for building hybrid energy sources (energy sources that use both fuel cells and electrochemical batteries or supercapacitors). Another major consideration is the selection of the type of storage used for the hydrogen that powers the fuel cells. The study contains research results that show the relationship between the electrical power of a fuel cell and the volume of hydrogen consumed during operation under a variable electrical load. In addition, it presents the results of experimental research on the implementation of low- and high-pressure hydrogen storage for fuel cell power supply. It is important to analyse the practicality of using distributed, renewable electrical energy sources for hydrogen production. The study describes the results of simulation and experimental research on the feasibility of generating electrical energy from photovoltaic (PV) installations, which are required to power modular electrolysers with a combined hydrogen production capacity of j = 2 Nm3/h. Variants of its usage as a carrier of hydrogen for powering fuel cells at different time periods are presented based on the analyses of hydrogen production capacity. The study also provides an analysis of the results of research on the use of PV-powered charging points for electrochemical batteries, or their electrical recharging with electrical power produced by a fuel cell-equipped generator. This research compared the weight, volume and achieved operating time of industrial standard electrochemical battery–based energy storage with those of hybrid units utilising hydrogen–air fuel cells. The study analyses and discusses the results in the context of using electrochemical sources for selected groups of mobile robots.

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Monitoring of radioactivity in building materials performed at IFJ PAN (Poland) between 2012-2024

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Gabriela Cieślachowska

Keywords: radioactivity, building materials

ABSTRACT

Monitoring the levels of natural radioactive isotopes such as ^{40}K, ^{226}Ra, and ^{228}Th or ^{232}Th in building material samples is crucial for assessing the potential ionizing radiation exposure of the population. The legislative requirements concerning the assessment of natural radioactivity in raw materials and construction products in Poland have undergone alterations a few times over the last decade. The Ordinance of the Council of Ministers (Polish Journal of Laws/Dz.U. No. 4/2007)[1] in force from January 2, 2007, until February 6, 2021, mandated the measurement of radionuclide activity concentrations: ^{40}K, ^{226}Ra, and ^{228}Th, along with the calculation of activity indices values f_1 and f_2. These indices determined the suitability of the mentioned materials for various construction applications. Subsequently, the Ordinance of the Council of Ministers (Polish Journal of Laws/Dz.U. No. 33/2021) [2] came into force on February 7, 2021, obliged to the measurement of radionuclide activity concentrations: ^{40}K, ^{226}Ra, and ^{232}Th, but it introduced a new parameter, the radioactive concentration index (I). The same law permitted building materials for market distribution in the Republic of Poland if the index (I) value is equal to or less than 1.

The Environmental Radioactivity Laboratory (ERL IFJ PAN), which works under the ISO 17025 accreditation regime, has been analyzing radioactive isotopes in building materials for many years. The most important finding is the presence of artificial radioisotopes (primarily ^{137}Cs) in ashes, commonly used as raw construction materials. This feature is a result of obligation of using of the biomass component in all fuels. This observation suggests a need for revision of radiological standards for mentioned materials. The algorithms used to determine potential ionizing radiation exposure should be supplemented by a component containing a dose contribution from ^{137}Cs [3].

The set of results obtained for radioactive isotopes in buildings materials during the last 12 years (2012 -2024) by ERL IFJ PAN will be presented at the conference.

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Hydrophobized vermiculite for the removal of petroleum-derived pollution

Elżbieta Vogt[1]

Keywords: hydrophobic sorbents, petroleum-derived pollution, vermiculite

ABSTRACT

In the current conditions of the extent of the use of oil-derived products they constitute one of the main sources of the pollution of the environment [1]. The use of mineral sorbents for the removal of oily substances allows the transition of pollutants from the liquid phase to the semi-solid, thanks to it is possible to remove them effectively from the environment. Even a slight modification of its hydrophobic properties may render these materials will be characterized by better parameters than the raw sorbents [2].

New hydrophobic sorbents were developed to remove oil-derived pollutants. The process of hydrophobization was conducted by the application of stearic acid and the commercially available silicone preparate Sarsil H-15. One studied different fractions of vermiculite. By determining the beneficial influence of the modifiers upon the selected sorption properties of various fractions of vermiculite one stated that there is a possibility to apply the modified materials, as sorbents for the removal of petroleum-derived pollution. The process of hydrophobization significantly enhanced the hydrophobic properties of all modified materials (Fig. 1).

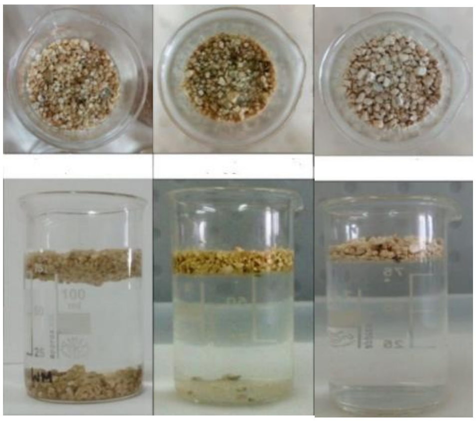

Figure 1. Flotation on water test: raw and modified samples, after 1 hour

All samples after modification were characterized by lesser absorbasbility and significantly greater capability of the adsorption of diesel oil from the surface of water in comparison with raw samples (Tab. 1).

Table 1. The adsorption of diesel oil from the surface of water

Sample	Capability of the adsorption [dm^3/m^3]
Raw material	80
Modified by steric acid	260
Modified by Sarsil H-15.	320

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ENERGY FUELS ENVIRONMENT EFE2024
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Advanced Carbon-based OER Electrocatalysts for Sustainable Energy Solution

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Keywords: carbon materials, electrocatalysis, oxygen evolution reaction, Zn-air batteries, water electrolysis

ABSTRACT

As the world population grows, the demand for energy continues to increase. The deterioration of fossil fuel reserves and the advancement of renewable energy sources require the transformation of efficient energy storage and conversion technologies. Hydrogen, with its high gravimetric energy density and zero CO2, is considered one of the most attractive energy carriers. Although it is primarily produced from nonrenewable energy sources, the importance of water electrolysis for green hydrogen production has been increasing.

Recent years have witnessed significant advances in ubiquitous electrical devices, driving increased user demand for thinner, more efficient, and durable devices. Promisingly, the development of zinc-air batteries offers an alternative to lithium-ion batteries that offers low cost, safety, environmental friendliness, and high energy density. Moreover, the use of solid electrolytes and flexible air electrodes enables the creation of flexible systems that can be applied, for instance, in unfolding screens.

Despite their apparent dissimilarity, both technologies face a common challenge, the oxygen evolution reaction (OER), which is crucial for their operation. However, the slow kinetics of this reaction diminishes the efficiency of these devices, limiting their widespread use. A potential solution lies in the application of suitable electrocatalysts, or electrode materials, which reduce the energy required for the reaction and consequently enhance its efficiency.

Although noble metals are considered the best OER electrocatalysts, their high cost and limited availability drive the search for new, cost-effective electrocatalytic materials. Carbon materials have emerged as an attractive group of electrocatalysts due to their unique properties, such as chemical inertness, thermal stability, and mechanical durability. Within this group, carbon nanostructures, such as nanofibers and nanotubes, stand out because of their exceptional electrical conductivity and high specific surface area, making them excellent OER electrocatalysts. However, they are often obtained in powder form, posing challenges for their application as electrode materials. Carbon cloth provides a solution, serving as a flexible, conductive, and easily modifiable substrate for the in situ synthesis of carbon nanostructures. This approach yields an electrocatalyst that combines the advantages of all these materials.

Moreover, utilising carbon cloth as a substrate for nanostructure synthesis offers an additional benefit. By modifying the surface of the carbon fibres in the cloth (e.g., using simple electrochemical methods), we can influence the properties of the resulting carbon materials. Any alteration in the physicochemical properties of carbon nanostructures affects their OER electrocatalytic activity.

The aim of the project was to synthesise materials with electrocatalytic activity in the oxygen evolution reaction that could be used as electrodes in both zinc-air batteries and water electrolyzers. To achieve this, we designed a synthesis to enable the in situ synthesis of carbon nanostructures on an electrochemically modified carbon cloth. The main research

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question addressed how the electrochemical modification of the carbon cloth affects the growth of carbon nanostructures and, consequently, their electrocatalytic properties in the oxygen evolution reaction from water. The studies conducted demonstrated that even a change in the position of a piece of carbon cloth during the electrochemical activation process significantly influences the size and structure of the carbon nanofibers obtained on it. Furthermore, electrochemical studies also revealed differences in the electrocatalytic properties of the materials obtained in the OER.

Acknowledgments: The research was founded by the Empiria i Wiedza Foundation under the research project "Talenty Jutra".

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ENERGY FUELS ENVIRONMENT EFE2024
26-28 JUNE 2024, KRAKOW, POLAND

Challanges and opportunities in the development of proton exchange membrane fuel cells (PEMFCs)

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Keywords: electrocataslyst, membrane electrode assembly, bipolar plates, balance of plant, hydrogen storage

ABSTRACT

Fuel cells (FCs) are promising new tools which directly transform chemical energy into electricity. Using hydrogen as fuel greenhouse gas emission is not involved [1]. Due to their relatively low operation temperature, high power density, short start-up, and high efficiency, proton exchange membrane fuel cells (PEMFCs) represent a very important group of FCs which are favorable for mobile applications. The technology readiness level (TRL) of the required PEMFCs determines the focus of the research which can be numerous. Main goal of this study is to tackle challenges, by using methods and by finding solutions at laboratory scale. These results should be scaled up which is possible by collaboration either with universities or industrial partners.

In case of laboratory scale, electrocatalyst development and characterization is usually the first stage and the first challenge. The electrocatalyst, most frequently carbon supported platinum is one of the key components which is responsible for the performance, longevity and price of PEMFCs. Beside the activity, the electrocatalysts have to be resistant to electrocorrosion in acidic media; their enhanced surface area and good electrical conductivity is essential. Different electrochemical measurements like cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) give useful information about the electrochemically active surface area (ECSA), about the resistance and capacitance of the catalyst. Next step is to characterize behavior of the catalyst in a real FC. For this, membrane electrode assembly (MEA) has to be prepared.

Catalyst coated surface (CCS) is prevalent method for manufacturing of MEAs in laboratory scale. In this case catalyst layer (CL) is painted onto the surface of the gas diffusion layer (GDL), which is usually carbon paper. Gas diffusion layer with the catalyst layer forms of the gas diffusion electrode (GDE). Hot-pressing of anode and cathode GDE with the PEM results the ready MEA. In case of catalyst coated membrane (CCM), as its name shows, CL is painted onto the surface of the PEM. This is the industrially preferred method, but lab scale version also exists. The quality of the MEA is a critical point; a spray-coating robot (Figure 1.) developed in our laboratory was able to make working MEA. The FC results obtained were better than in the case of using a simple AIRBRUSH spray-coating.

Development of PEM is an also important scope of the FC research. The membrane should have high ionic conductivity, low H_2 crossover, good thermal, electrochemical, and mechanical properties in dry and hydrated states Nowadays, almost exclusively the Nafion® membranes of DuPont are used as PEMs. Although Nafion provides excellent proton conductivity the other properties of the membranes should be developed. One of the most important challenge is to find a more environmental-friendly manufacturing method of PEMs.

After, the catalyst and the PEM are available, and manufacturing MEA is possible, the fuel cell can be put together. Material and geometry of bipolar plates (BPPs) are also very important, because a well-chosen gas flow field is able to increase the power of the cell.

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There is a large variety of different technical solutions [2]. It is important to emphasize that the goal is different in case of the design of a lab scale and the arrangement of an industrial scale BPP. In case of laboratory research cells, easy remountability and roboustness is crucial, because MEAs are changed from measurement to measurement. In real applications FC stacks are not dismountable. They are very compact, as a result of the optimization to reach the largest electric power with the smallest possible stack size. FC stack itself is not enough to work alone in a real application's environment. Balance of plant (BOP) means the whole system, which is necessary to use fuel cells [3]. BOP contains the stack, humidifier, gas cylinder, pressure reducer, cooling unit, and small sized battery or supercapacitor to buffer currents of start-up/shut-down (SUSD). Required power and application environment determines that closed cathode or open cathode PEM cells should be used. In laboratory scale closed cathode version is more prevalent. Open cathode stacks are able to reach less power than same sized closed cathode ones, but their BOP is much more simple (because of their cooling and cathode gas feed is the same system). Because of that, open cathode PEMFC stacks are advantageous in light, portable applications, where space is limited and weight is crucial, for example in case of drones.

Importance of collaborations was mentioned in the beginning. Finding the market gap next to the large FC manufacturers is difficult. Micromobility can be the area for R&D institutes, where higher TRL levels can be reached, and new results can be demonstrated. In case of our cooperation: our research group develops MEAs, the ArtTECHNICS Bt. (industrial partner) develops BPPs, Budapest University of Technology and Economics (university partner) develops BOP regulation system) while John von Neumann University (university partner, Kecskemét, Hungary) develops H_2-cylinders.

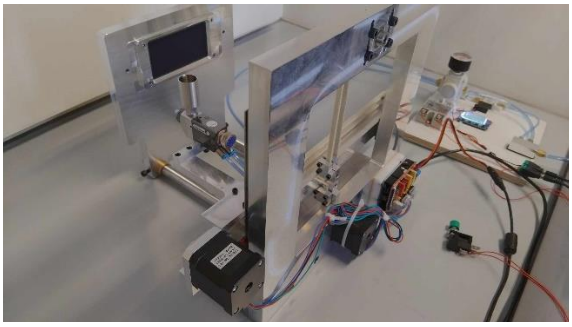

Figure 1. Spray-coating robot for MEA preparation

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Pilot research on CO_2 hydrogenation process for E-methane and E-methanol

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Keywords: Synthetic natural gas, Methanol, Carbon capture, Energy storage, Hydrogenation

ABSTRACT

This paper summarizes the initial operation experience and selected results obtained during largest in Poland, Power to Gas project called CO2-SNG. Supported by KIC Inno Energy project aims to develop a technology for energy storage. This article also includes selected experiments on the synthesis of CO_2 and H_2 into e-methanol, as another synthetic fuel with practical properties in energy storage.

UE countries are leading in CO_2 emission reduction. There are several technological solutions recognised for CO_2 capture, transport and storage (CCS). However, application of full-chain CCS is currently difficult because of low social acceptance for transport and CO_2 storage. On the other hand, EU countries have defined also the objective that at least 20% of their energy will come from renewable sources in 2020. The disadvantage of renewable sources like solar and wind energy is their intermittency resulting in a fluctuation of their production from over hourly to seasonal periods. The CO2-SNG project was devoted to solve simultaneously the CO_2 utilization and renewable electricity storage problems.

Figure 1. Integrated CO2-SNG and CO_2 Capture pilot plant system view at the Łaziska Power Plant [1]

The process for converting of the surplus electricity from renewable energy sources into e-methane (SNG - synthetic natural gas) was investigated by Polish and French partners of the project with the goal of its commercialization as a profitable technology for electricity storage. The SNG may be delivered to existing natural gas network utilizing its storage capacity or may be compressed and used as CNG for public transport. The general principle of process is to convert CO_2 captured from industrial facilities (e.g. coal-fired

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power units, chemical, metallurgical or cement plants) into e-methane in the highly exothermic reaction with hydrogen coming from water electrolysis powered by excess and cheap renewable electricity from the grid.

One of the milestones was to design and erect CO2-SNG pilot plant at the power station of the project leader, TAURON, second largest energy producer in Poland. The pilot plant can convert up to 200 kg/day of CO_2 captured from the flue gas of power unit [2]. To be compatible for the use of renewable electricity, the plant has been designed to work with a large range of parameters, up to 350°C and 15 bar, and from 20% to 100% of the nominal capacity. The research, comprising over 40 tests, examined CO_2 conversion to methane. Results showed high repeatability, temperature's positive correlation with conversion rates, pressure's significant impact, and optimal gas cooling at 90°C. An optimized group of parameters allowed a high degree of CO_2 conversion to be achieved, up to 98% (Fig.2). Findings offer insights for industrial application and process optimization.

The core technology for the methanation reactor with catalyst was delivered by French partners of the project. Several dedicated testing campaigns were performed by Institute of Energy and Fuel Processing Technology in Poland (ITPE). The technical and economic documentation of the final market product – a larger scale CO2-SNG system will be delivered by TAURON and other Polish partners.

The experience gained allowed the ITPE team to start research and develop a reactor concept to synthesize CO_2 and H_2 into 5 dm^3/h e-methanol. This fuel has better energy storage properties and could be attractive in the fuel and transport sector.

An additional advantage of both processes is the possibility of their deep integration with carbon capture process (CCP). Usually CCP requires significant amount of heat which, in this case, can be taken from both exothermic reactions. CO_2 for the process can be delivered by the Amine-Based CO_2 Capture pilot plant, where advanced construction of stripper is applied with possibility of using external heat in the column [2].

From a social and political point of view, the Power-to-X concept combines three important elements of the energy transition: renewables, hydrogen and synthetic fuels into one complementary system that leads to the sustainable and secure development of the entire energy system.

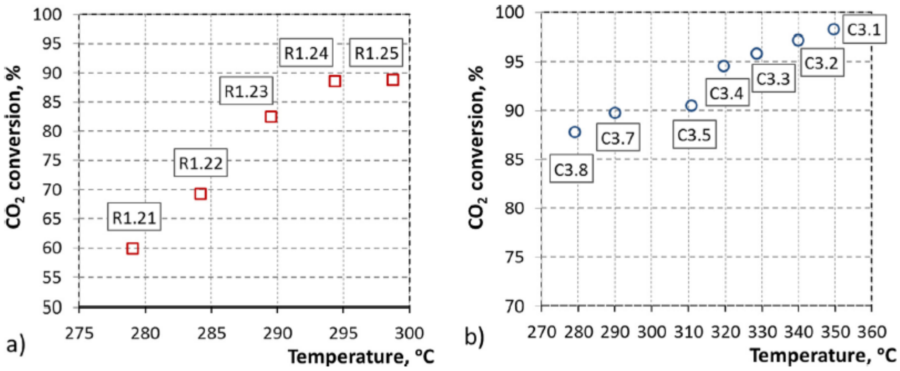

Figure 2. The effect of temperature on CO_2 conversion rate a) – first reactor stage, b) – second reactor stage at the gas flow of 10 kg/h and pressure of 3.0 bar,temperature of first stage 300 °C.

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Brewery as a biorefinery. Spent grain simple fermentation towards obtaining bioethanol

Katarzyna Kapusta[1],*, Katarzyna Moskalewicz[1], Wojciech Wójtowicz[2]

Keywords: brewery spent grain, biorefinery, fermentation, bioethanol, yeasts

ABSTRACT

In 2022, the brewing industry in European Union produced 34.3 billion liters of alcoholic beer and 1.6 billion liters of non-alcoholic beer or beer contained less than 0.5% alc [1]. Producing 100 liters of drink is equivalent to producing 20 kg of wet solid waste, i.e. brewer's spent grain (BSG). Poland is the fourth producer of beer in EU. Polish breweries produced almost 4 billion liters of beer, producing 800 million kg of BSG. Fresh residue is made of c.a. 85% water and some solid matter. Due to high water content, its shelf life in our climate is 48 hours, so there are problems with its transport and storage. Dry BSG contains mainly polysaccharides (approximately 70-75% dry matter), some proteins (20-24%), and a small amount of lipids (2-6%). About 70% of BSG is transferred to the agricultural industry, 10% is used in technological processes and 20% is stored in landfills. [2, 3]

There are about 300 breweries in Poland, most of which are regional, craft, and restaurant breweries. They are responsible for only 10% of the beer production, but their market share is constantly growing. One of the factors limiting their development is waste management. The produced spent grain is usually taken away by farmers free of charge. The problem comes when the local agricultural market is not interested in cooperation.

A model enterprise that meets the assumptions of circular economy is a biorefinery, the heart of which can be any plant that continuously generates biological waste. In the literature, the concept of a biorefinery is strongly associated with a brewery which, in addition to producing beer, could process waste in such a way as to obtain fuels, energy, or chemicals. Knowing both the requirements of processing processes and the realities of work in Polish breweries, the best solution seems to be to design and optimize processes in such a way that their implementation is profitable and as "painless" as possible in terms of space and finances. Therefore, it is necessary to try to process brewer's spent grain using equipment that the brewery already has at its disposal.

The work presents the results of research on the simple fermentation of BSG using waste yeast slurry to obtain bioethanol. Fresh and dried spent grain were boiled with water, and then the resulting solution was inoculated with yeast and left to ferment for a week. To ensure optimal conditions for the yeast to work, the pH of the solution is adjusted using lactic acid which is used to regulate pH during beer production. Other than that, no additional chemicals were used. As a result of the experiment, an aqueous solution of ethanol with a low concentration was obtained.

The work also includes proposals to improve the efficiency of the spent grain fermentation process and the concept of placing the process in the brewery's production line.

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Effective fluorine-free blend membranes made from sulfonated Polyvinyl Alcohol (S-PVA) and PEBAX 1657 with Titanium dioxide sulphate TiO_2SO_4 as Nano filler: exploring the impact of various filler ratios on PEMFC applications

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Keywords: proton exchange membrane fuel cell, fluorine-free, sulfonated polyvinyl alcohol (S-PVA), PEBAX, Titanium Dioxide Phosphate (TiO_2SO_4)

ABSTRACT

The importance of fuel cells is needless to be detailed. Sustainable and environmentally friendly solutions in this research area are able to be competitive alternatives to fossil-based energy sources. There are numerous potential paths for proton exchange membrane fuel cell (PEMFC) development. The important way is through PEM development, which is essential for membrane electrode assemblies (MEA). PEM fuel cells use polyperfluorosulfonic acid (PFSA) membranes, including Nafion, as electrolyte membranes due to their exceptional proton conductivity, robust mechanical strength, and superior chemical and thermal stability. Nevertheless, the substantial cost of Nafion and its reduced stability at elevated temperatures hinder its widespread use. The main goal of this study is to search for suitable alternatives due to its excessive cost and various drawbacks, particularly when operating at elevated temperatures or reduced humidity. One way to improve the performance of the proton exchange membrane is to use a variety of hydrocarbon polymers as the main polymer chain when synthesizing and testing blend membranes inside fuel cells (PEMFC). This study aims to investigate the potential of non-fluorinated membranes composed of sulfonated polyvinyl alcohol (S-PVA) and polyether block amide (PEBAX 1657) with incorporate TiO2SO4 as Nano filler.

Novel blend membranes containing 10% S-PVA and 3% PEBAX 1657 with a blend ratio of 8:2 were prepared. Titanium Dioxide Sulphate (TiO_2SO_4) in ratios of 0%, 3%, 5%, and 7 as a nanoparticle filler was added. The membranes were fabricated using the solution-casting technique. Our goal was to investigate the interaction between the TiO_2SO_4 Nano filler and the blend polymer matrix. As shown in Table 1, the thermogravimetric analysis (TGA) results for the composite membranes enhance their heat resistance and highlight the role of Titanium Dioxide Sulphate (TiO_2SO_4) as an effective nanoparticle filler when added to blend polymers.

Table 1. Carbonaceous residue (%) were obtained at a temperature of 900 °C for SSP blend membranes with and without different TiO_2SO_4 content.

Samples	Carbonaceous residue (%) at 900 °C
S-PVA:PEBAX 0% TiO_2SO_4	15.54 %
S-PVA:PEBAX 3% TiO_2SO_4	20.13 %
S-PVA:PEBAX 5% TiO_2SO_4	21.55 %
S-PVA:PEBAX 7% TiO_2SO_4	22.40 %

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With an acceptable swelling degree of 31.08% and the highest water uptake of 50.88%, the composite membrane with SPP 7% TiO_2SO_4-coded membrane seems to be very promising for fuel cell applications. At ambient temperature, the composite membrane with a 7% TiO_2SO_4 composition displayed the greatest ion exchange capacity, reaching 1.03 meq/g, surpassing that of other composite membranes. A fuel cell performance test Figure 1 shows that the SPP 7% TiO_2SO_4 membrane has the highest current density and power density of all the membranes that were made. It has 186.97 mA/cm^2 and 46.15 mW/cm^2. The optimal distribution of TiO_2SO_4 as a filler indicates that these membranes are promising for PEMFC applications.

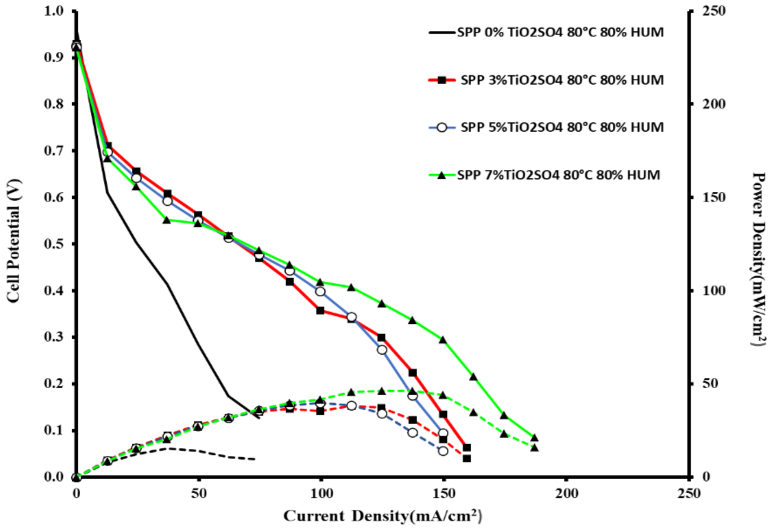

Figure 1. The polarization curves and power density curves illustrate the performance of SPP blend membranes with and without varying TiO_2SO_4 content. The simple line refers to S-PVA:PEBAX 0% TiO_2SO_4, the ▪ signed line refers to S-PVA:PEBAX 3% TiO_2SO_4, the ▪ signed line refers to S-PVA:PEBAX 5% TiO_2SO_4 and the ← line refers to S-PVA:PEBAX 7% TiO_2SO_4.

Synthesis of magnetic activated carbons as efficient adsorbent of trivalent chromium from aqueous solutions

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Keywords: magnetic activated carbon, heavy metals, trivalent chromium, adsorption

ABSTRACT

Water pollution with heavy metals such as arsenic, chromium, mercury and lead has become a major environmental concern. Toxic impact on human health is reflected in their carcinogenic, mutagenic and teratogenic effects. Chromium is classified as one of the most abundant heavy metal on Earth [1]. Two stable forms of chromium in aqueous environment are trivalent Cr(III) and hexavalent Cr(VI). The most dangerous chromium form *i.e.* Cr(VI), is being released into the water from dyeing, tanning, electroplating, and chromate synthesis industries. On the other hand, Cr(III) is an important microelement, nearly 300-fold less toxic than its hexavalent counterpart. However, due to the risk of Cr(III) oxidation to Cr(VI), the overall chromium content in the environment must be strictly monitored. The most common methods of chromium removal involve electrodialysis, membrane technologies, coagulation, and adsorption. Among them, adsorption is considered the cheapest and most efficient [2].

Commonly used chromium ions adsorbents involve: biochars, zeolites and activated carbons (ACs) [3]. AC due to its high porosity, high surface area, increased absorptivity, and chemical stability, has become one of the most efficient adsorbents of both organic and inorganic pollutants from aqueous environment. To improve its adsorption properties and ease isolation from the aquatic environment, magnetic iron nanoparticles can be introduced into their surface [4].

In this study, a series of commercial activated carbons (CWZ) were modified with a mixture containing $FeCl_3$, $FeCl_2{\cdot}4H_2O$ and ammonia of various ratio, aiming to form magnetic ACs. Materials were then characterized by means of XRD, implying that the mixture affected the structure of AC and iron nanoparticles were introduced into the surface of ACs. With increasing dose of modification mixture, the peaks of AC diminished. To investigate the potential utility of obtained magnetic ACs, materials were subjected to static adsorption of Cr(III) ions from aqueous solutions. It was confirmed that, with increasing dose of modification mixture, the adsorption capacity towards removal of Cr(III) did not change and was as high as 25 $mg{\cdot}g^{-1}$. However, the carbons were easier to remove from the solution by simple adjustment of magnetic field.

Modification of activated carbon with iron nanoparticles allows to obtain materials with improved separation properties. By simple introduction of magnetic field, allows better regeneration of adsorbent with simultaneously maintained adsorption capacity.

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Prediction of wind turbine productivity as a necessity for proper maintenance planning

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Keywords: maintenance planning, prediction of productivity, renewable energy sources, wind turbines

ABSTRACT

The speech presents challenges related to productivity prediction of wind farms. Productivity prediction and balancing of electricity generated by renewable energy sources have recently become significantly more important both in Poland and in Europe as a whole. This situation will be significantly intensified with further changes taking place in the power systems of European countries. This is particularly evident in the Polish Power System (PPS), where in recent years there has been a significant change in the structure of the installed capacity of energy sources.

Between 2017 and 2023, the installed capacity of renewable energy sources increased from 6,3 GW to 27,2 GW (see Table 1). At the end of 2023, the installed capacity of photovoltaic sources was more than 17 GW while the installed capacity of wind farms was 9,4 GW.[1]

Table 1. PPS installed capacity by type of energy source on 31 December.[2][3]

Type of source	2017		2023	
	Power [MW]	Percentage share [%]	Power [MW]	Percentage share [%]
Total	**43 421**	**100,00**	**67 770**	**100**
Hydroelectric power plants	2 328	5,36	2 426	3,58
Hard coal-fired power plants	20 247	46,63	25 111	37,05
Lignite coal power plants	9 352	21,54	8 284	12,22
Gas-fired power plants	2 341	5,39	4 732	6,98
Wind farms and other renewable power plants	6 341	14,60	27 217	40,16
Industrial power plants	2 813	6,48	-	-

The consequence of such a high diversification of sources in the PPS is the fluctuation of energy prices on the Polish Power Exchange ('TGE') in the Day-Ahead Market ('DAM') quotations. There is an increasing incidence of negative electricity prices on summer and spring weekends and holidays around midday. This is caused by the large generation by photovoltaic and wind farms at the same time, while there is not much demand for

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electricity. Negative electricity prices on the TGE were not encountered until 2023 [4], but with the dynamic change in the installed capacity structure of the PPS, the situation has changed radically. According to expert's opinions and the examples of the electricity systems of other EU countries, such as Germany, the situation of negative energy prices will happen more and more often with the increase of the installed capacity of Renewable Energy Sources (RES).[5]

Negative energy prices are not the only negative consequence of the changes that have taken place in the capacity structure of the PPS. The Transmission System Operator (TSO) must increasingly issue orders to reduce electricity generation by wind farms and photovoltaic sources. Polish TSO issued orders to reduce electricity from RES sources 5 times during 2023, while from January to 12 May 2024 there were 22 such cases. [6]

The speech presents the results of analyzes taking into account the occurrence of negative price events and their impact on the possibility of planning the service and maintenance of an offshore wind farm. Based on historical data, it can be indicated that the highest generation occurs during the autumn and winter months. However, it is quite difficult to indicate the specific hourly ranges in which the highest amount of energy is generated from wind farms. [7] It is already proven that in order to build a productivity prediction tool, it is necessary to carefully analyse the technical data and performance of the individual turbines that make up the wind farm. Research work to date has focused on predicting the productivity of the wind farm as a whole. However, this approach may not be sufficient to accurately predict the energy produced by wind farms. Things are even more complicated for offshore wind turbines with an installed capacity of 12-15 megawatts. For wind speeds in the range of 5-11 m/s, each 1 m/s change in speed can result in a change in generated power of about 2 MW per turbine. [8]

The results of the analysis indicate that for accurate prediction of electricity production by a wind farm at particular hours of the day, it is necessary to make a prediction for each turbine individually, taking into account parameters such as forecast wind speed and direction, air temperature, humidity and technical availability. It is highiglighted that the impact of turbine shutted down on the change in power generated by neighbouring turbines can be significant. The more accurately the wind farm operation is analysed, then the more precise the prediction results can be for the wind farm operator. This can result in better planning of operational work and increased revenue generated by the wind farm.

Proper and accurate modeling of the production forecast is closely correlated with the optimalisation of the costs of operating wind farm by developing an appropriate strategy for servicing and maintaining. It is proven that proper forecast of energy production will allow one to optimally manage negative price events by taking these events into account for the needs of a service campaign or using energy to power batteries, electrical appliances or other energy-consuming devices.

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Characterization of Particulate Matter with Identification Sources of Pollution in Krakow

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Keywords: $PM_{2.5}$, PM_{10}, air pollution, sources

The air pollution is one of the most meaningful environmental problem in cities. Observations of air pollution in Krakow have shown that air quality has been improved during the last decade. In the presented study two factors influenced the physicochemical characteristic of $PM_{2.5}$ and PM_{10} fractions at AGH station in Krakow. First is the ban of using solid fuels for heating purposes and the second is COVID-19 pandemic in Krakow. $PM_{2.5}$ and PM_{10} fractions were collected during the whole year between 2020 and 2021 at AGH station in Krakow. The results of study for $PM_{2.5}$ were compared to analysis performed for the period from 2018 to 2019 [1].

Chemical composition of air particulate matter samples was determined by Energy Dispersive *X*-ray Fluorescence technique utilizing in-house constructed secondary target excitation system. The system, based on 3 kW Mo-anode *X*-ray tube with Ni and Mo secondary targets, was operated in air at atmospheric pressure. Ions concentrations were determined by isocratic ion chromatography on an ICS-1100 instrument (Thermo Scientific). Moreover, this study presents yearly variations in equivalent black carbon (eBC) concentrations. Light absorbing carbon (LAC), also presented as eBC, is generated from the partial combustion of fossil fuels and biomass [2]. The scientific interest in eBC is large because its contribution to the $PM_{2.5}$ fraction is high, especially in urban areas. The transmissions of light at different wavelengths were measured by a multi-wavelength absorption black carbon instrument (MABI).

In order to identify the emission sources Positive Matrix Factorization (PMF) were used. Four factors were obtained from PMF modelling and the following sources were attributed to them: road dust/construction work/industry/soil, exhaust traffic and solid fuel combustion as well as secondary inorganic aerosols. The results show, that the annual $PM_{2.5}$ concentration dropped in 2020/2021 in comparison to 2018/2019 by about 25%.

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Hydrogen Refueling Station Location in Railway Network – Strategic Management Perspective

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Keywords: hydrogen refueling station, railway network, refuelling station location problem, critical infrastructure location, strategic decision-making

ABSTRACT

Site selection is a crucial long-term decision involving the choice of locations for one or more facilities within a planning area to optimize specific targets. This process is widely applicable across production, daily life, logistics, and military operations [1]. It becomes especially vital when implementing new technologies that can significantly impact the sector or the broader economy [2].

The research discussed in this paper centers on the adoption of hydrogen propulsion technology in rail transportation. Rail networks, with their fixed track systems, have limited flexibility. Therefore, the strategic placement of hydrogen refueling stations is essential for advancing hydrogen energy and fuel cell technology in the railway industry [3-5].

For addressing the problem of locating hydrogen refueling stations within a railway network, an approach based on the Economic Order Quantity (EOQ) problem was adopted. This optimization problem incorporates various constraints such as fuel demand, hydrogen availability, and infrastructure costs. Mathematical modeling, particularly linear and integer programming, is a key tool in this approach. Several Mixed-Integer Programming (MIP) models were developed to determine the optimal locations for hydrogen refueling stations based on specific decision criteria. This approach allows decision-makers to analyze multiple scenarios and the optimal solutions derived from them.

The identified optimization problems and their associated mathematical models represent a significant step toward understanding the relationship between the placement of hydrogen refueling stations and the deployment of hydrogen propulsion in railways. By utilizing mathematical modeling and analyzing the optimal solutions across different scenarios, decision-makers can map the influence of individual parameters—such as demand, hydrogen purchase or production costs, and station types—on strategic decisions.

As facility location problems are part of long-term strategic decision-making, two primary models are presented: (1) a single-period model that provides an overview of the relationships among demand, supply, available locations, and fixed and variable costs, and (2) a multi-period model that includes additional economic factors influencing the introduction of new technology into a strategic transportation sector, such as projected demand growth and changes in hydrogen generation costs.

Newly developed Mixed-Integer Linear Programming (MILP) models for the complex problem of deploying hydrogen refueling stations are presented, illustrated with exemplary solutions for selected data instances based on the hydrogen deployment strategy for railways in Poland.

The research was conducted as part of the Europe's Rail Flagship Project 4 - Sustainable and green rail systems, WP9 Interoperable Hydrogen Refueling Station, DOI: 10.3030/101101917.

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Optimization of Flue Gas Cleaning Installation Based on CFD Simulation of a Power Boiler Operation

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Keywords: CFD, Sulfur Oxides, Combustion Chamber, Circulating Pumps

ABSTRACT

In the era of increasing shares of renewable energy sources (RES) and the liberalization of the energy market, the dynamic and flexible operation of power blocks based on boilers becomes crucial [1]. Computational Fluid Dynamics (CFD) plays a fundamental role in optimizing combustion processes, improving energy efficiency, and minimizing the emission of harmful substances into the atmosphere [2,3], which translates into reducing the negative impact on the environment.

Optimizing the operation of wet flue gas desulfurization installations (WFGD) installations becomes not only a technological issue but also a strategic one, enabling the energy and processing industries to achieve better compliance with environmental regulations while minimizing the impact on the natural environment.

This paper presents a method for running a flue gas desulphurization system, considering the optimal operation of the circulation pumps and reducing operating costs. As part of the work, a CFD model of the combustion chamber of boiler OP-430 was prepared, allowing for the determination of sulphur oxide emission characteristics depending on the boiler load.

The developed numerical model was validated based on measurement data from the actual OP-430 power boiler. Four power blocks are connected to the flue gas desulfurization system in the analysed system. For the proper operation of the WFGD system, the flue gas temperature must be maintained at 110°C, and the sulfur oxide content must be within the range of 1100 ÷ 3200 mg/Nm³.

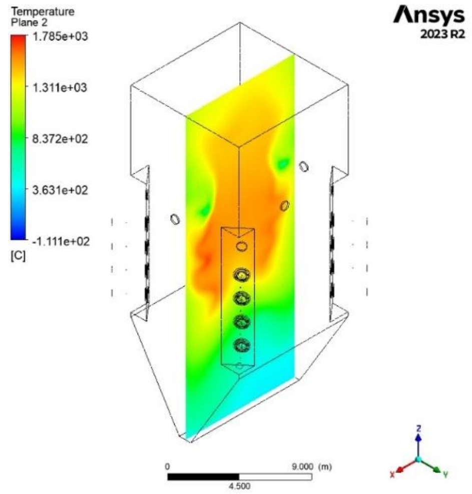

Figure 1. Temperature distribution in the combustion chamber

The scope of the work conducted is significant for the operation of the desulfurization system, as proper operation requires maintaining the sulfur content at the outlet of the system below 200 mg/Nm³. Thanks to the results obtained from the simulations of boiler operation at different loads, it was possible to determine the guidelines for operating the wet flue gas desulfurization system for the economical operation of WFGD.

As a result of the simulations conducted, the flue gases' temperature distribution throughout the combustion chamber's volume and the concentrations of various substances were obtained (Fig 1). The amount of flue gases produced during the combustion process in the boiler and the amount of sulfur were read from the numerical calculations to determine the sulfur load at the outlet of the combustion chamber.

Table 1 presents the values read from the numerical calculations of the chamber for all nine analyzed cases, recalculated for the flue gas temperature before the WFGD of 120°C. One of the factors affecting the amount of sulfur at the outlet of the wet flue gas

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*corresponding author: marcin.trojan@pk.edu.pl desulfurization installation, under identical inlet conditions to the WFGD, is the number and configuration of the operating circulating pumps. Four circulating pumps push the slurry from the absorber to four individual spraying levels. Each of the four circulating pumps has a capacity of 7000 m³/h, which means that while maintaining the same performance, pushing the medium to different heights, the pumps have different power levels, which, in turn, translates into electricity consumption. For the safety of the installation, two pumps must be operated. The power consumption by all four pumps varies. The maximum amount of SO2 at the inlet to the WFGD system and the electricity consumption for different pump operation configurations are shown in Table 2.

Table 1. Read values for the analyzed cases

	Measurement					CFD calculations	
Boiler load	Steam output from the boiler	SO_2 content	Amount of flue gases	Amount of flue gases	SO_2 load at the outlet of the combustion chamber	Amount of flue gases	SO_2 load at the outlet of the combustion chamber
[%]	[t/h]	[kg/Nm^3]	[1000xm^3/h]	[Nm^3/h]	[kg/h]	[1000xm^3/h]	[kg/h]
60	250	0.001307	256.9	174100	226.50	260.6	228
65	272.5	0.00126	277.7	190500	240.03	272.3	247.2
70	296	0.001566	316.1	216800	339.51	310	346.8
75	318.5	0.001663	334.9	227800	378.83	342.8	370.5
80	342.5	0.001676	347.1	231600	388.16	352.2	376
85	363.7	0.001576	373.6	255000	401.88	382.2	409.7
90	382.5	0.001803	376.6	251300	453.09	379	446.8
95	408.6	0.001687	410.7	273100	460.72	417.8	451.7
100	430	0.001587	452.7	300600	477.05	445.8	470.3

Table 2. Electricity consumption for individual pumps

Configuration	SO_2 load at the inlet [kg/h]	SO_2 load at the outlet [mg/h]	Electricity consumption [kWh]
Pumps 1-2	1306	199	1354
Pumps 1-4	1660	199	1447
Pumps 2-3	1813	199	1484
Pumps 3-4	1470	199	1577
Pumps 1-2-3	1581	199	2115
Pumps 1-2-4	2022	199	2170
Pumps 3-4-1	2738	199	2207
Pumps 2-3-4	2706	199	2300

Using the determined characteristic of the amount of sulfur at the outlet of the combustion chamber at a given boiler load (from CFD modeling), it is possible to plan the operation of circulating pumps in the WFGD at the planning stage of the operation of power blocks.

The presented mathematical model of the combustion chamber enables precise determination of the concentration of all harmful substances, providing a solid foundation for developing integrated flue gas cleaning systems. The combustion chamber model offers the possibility of identifying key parameters affecting the emission of harmful substances and allows for the optimization of combustion processes in terms of minimizing emissions.

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Optimizing Microgrid Energy Management with micro-scale Compressed Air Energy Storage

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Keywords: Energy storage, Microgrid, Energy management

ABSTRACT

Driven by population growth and technological advancements, global energy demand is rapidly rising. To address this challenge and create a more sustainable future, increasing the share of Renewable Energy Sources (RES) in the power grid is also essential. RES are usually characterised by intermittent and weather-dependent energy generation [1]. Therefore, balancing energy supply and demand is a growing challenge for the energy sector [2]. The variability in the generation profile indicates the necessity of integrating energy storage solutions (or other control strategies) to avoid energy waste during peak generation and to use it during periods of highest demand. This paper investigates the integration of micro-scale compressed air energy storage (CAES) with distributed RES, including photovoltaic (PV) panels and wind turbines, within a microgrid framework. As a case study, we analyze the feasibility of implementing such a system for 19 houses in northern Portugal. We utilize real data on electricity consumption from E-Redes' Open Data Platform [3] and data for solar and wind potential estimated using Renewable Ninja [4]. Using EnergyPLAN [5] software, the authors analyse and select the parameters of both the energy production and storage system to strive for the independence of the microgrid and the highest efficiency of the system. Computer simulations allow us to obtain charging and discharging curves for the energy storage system based on the available renewable energy. Figure 1 presents the storage usage in the microgrid system throughout the year.

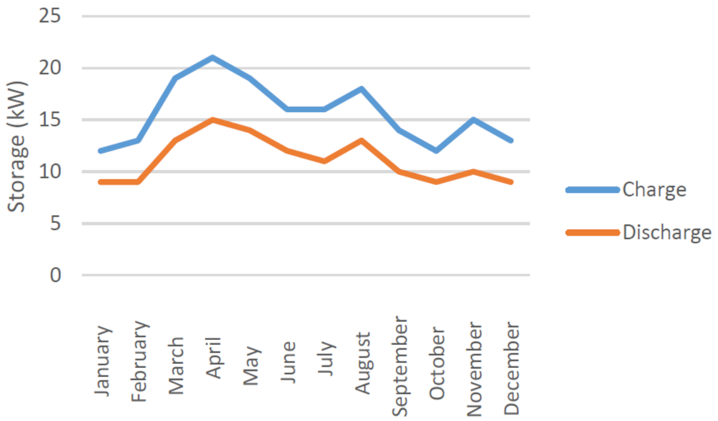

Figure 1. Charging and discharging of the storage system throughout the year

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The heat and mass transfer intensification methods: fluidization and micro/nano bubbles - achievements and concepts

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Keywords: adsorption and desalination system, heat transfer, mass transfer, fluidisation, micro/nanobubble

The concept of sustainable development has long been a focus for scientists and engineers. The continuously increasing prices of energy and fossil fuels compel them to explore new ideas and solutions that can facilitate more efficient utilization of available resources. When examining refrigeration systems and exploring avenues for more sustainable alternatives, the implementation of adsorption chillers emerges as a promising approach in adsorption cooling and desalination technology. Unfortunately, the adsorption chillers still possess factors limiting the possibilities of their industrial implementation. [1], [2]

One of the factors that hinder the utilization of adsorption refrigerators is their low coefficient of performance. One way to increase energy efficiency is by intensifying heat and mass transfer in the adsorption bed. It may be achieved by changing the geometry of the bed and heat exchangers, modifying the structure of the sorbent layer, or employing adsorbent fluidization. Additionally, increasing energy efficiency can be achieved through the use of modern adsorbents or the utilization of internal heat recovery [3].

Fluidization has proven to be an effective means of enhancing mixing processes responsible for its improved heat and mass transfer in adsorption beds. However, there is still room for improvements. Therefore, on the one hand, we propose to exploit the fluidization of the packed bed as a means to improve mass and heat transfer in the adsorbent bed. On the other hand, we present a novel concept of utilizing micro/nanobubbles for augmenting mass and heat transfer in the heat exchanger tubes of an adsorption chiller. The injection of micro and nanobubbles will enhance the turbulence of the fluid flowing through the heat exchangers located in the sorption bed, evaporator and condenser of the adsorption chiller. Literature studies have demonstrated the effectiveness of using air injection for enhancing heat transfer in heat exchangers. However, the application of micro/nanobubbles in adsorption chiller heat exchangers has not yet been explored. Thus, the concept presented here opens up a new research direction and provides opportunities for introducing new ideas and concepts into adsorption cooling [4], [5], [6].

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Innovative, integrated offshore production of green H_2 form Baltic sea

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Keywords: Green Hydrogen Production, Seawater Desalination, Offshore Platforms

ABSTRACT

The current geopolitical landscape, combined with the escalating challenge of climate change, is accelerating the development of environmentally friendly energy technologies. A significant example is hydrogen technology, known for its potential to drastically reduce atmospheric pollutant emissions. Hydrogen is versatile, acting both as an energy carrier and a substrate in various industrial applications. Given the challenges related to water availability, it's critical to consider the long-term water requirements for hydrogen production. Forecasts indicate that by 2050, the global demand for electrolytic hydrogen will reach 74 exajoules (EJ), with two-thirds expected to be green hydrogen. This production level will require a water supply of approximately 24.8 billion cubic meters (bcm), sourced entirely through seawater desalination. The associated costs of treatment and transportation are projected to be less than 2%, and the energy required for desalination will constitute about 1% of the total energy needed for hydrogen production. As a result, the intake of seawater from seas and oceans could increase by 2.5 to 5 times. This article presents a project dedicated to producing hydrogen from Baltic Sea water on an offshore platform. The primary objective of this project is to gain invaluable knowledge and experience to support the development of a commercial-scale seawater hydrogen production facility. The pilot system on the offshore platform includes electrolysers capable of producing 10 kg of hydrogen per day, an ultrapure water preparation system, a gas turbine combustion engine, and a hydrogen storage system. The ultimate outcome of this project is to establish a fully integrated and autonomous system for off-grid green hydrogen production, storage, and utilization. This system aims to provide a sustainable and low-carbon energy solution that is independent of the electrical grid, offering potential benefits across various sectors of the economy.

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Oxidative potential of PM$_1$, PM$_{2.5}$ and PM$_{10}$ collected in road and tram tunnels in Krakow, Poland

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Keywords: Oxidative potential, Trace elements, Heavy metals, Air pollution, Antioxidants, Environmental pollution.

ABSTRACT

Evaluating the oxidative potential (OP), which measures a substance's ability to oxidise other compounds, indicating its reactivity and environmental impact of airborne particulate matter, can serve as a method for assessing health-related exposures by incorporating a range of biologically pertinent characteristics of particulate matter. The aim of this study is to quantify the oxidative potential of particulate matter within two distinct size distributions, through the application of analytical methodologies of ascorbic acid (AA) and reduced glutathione (GSH). The collection of samples and the investigation involved the acquisition of particulate matter specimens in Krakow car and tram tunnels presented in the figure 1, which is identified as one of the urban areas with the most significantly impacted by pollution in Poland, with a particular focus on the central area. The samples were collected in the months of March, April and July at intervals of 24 hours for 24h samples, at intervals of 12 hours for night and day (Table 1). The observed concentrations of PM$_{10}$, PM2.5 and PM$_1$ ranged between 8 µg m−3 to 298 µg m−3 (car tunnel) and from 31 µg m−3 to 127 µg m−3 (tram tunnel), respectively. These samples were subjected to chemical analyses to determine the elemental carbon, organic carbon, ion, and metal content. The findings indicated that the PM$_{10}$ particles exhibited greater oxidative activity in the car tunnel, with the depletion of OP$_{AA}$ and OPGSH reaching as high as 23 µg m−3 and 21 µg m−3 (car) and in the tram tunnel it varies to 28 µg m−3 in PM1 and 24 µg m−3. The average values of the depletion of OP$_{AA}$ and OP$_{GSH}$ during 90 min of incubation time of the PM10, PM2.5 and PM1 car tunnel were 15.9 ± 4.9 and 11.9 ± 5.2 µg m−3, and 15.7 ± 4.9 µg m−3 and 13.0 ± 5.4 µg m−3, and 10.9 ± 7.5 µg m−3 and 6.3 ± 3.2 µg m−3, respectively. For reaching an average of tram tunnel, OP$_{AA}$ and OP$_{GSH}$ are 13.8 ± 6.3 and 10.9 ± 5.3 µg m−3, and 16.0 ± 6.3 and 12.7 ± 5.0 µg m−3, and 11 ± 11 µg m−3 and 10.4 ± 6.1 µg m−3, respectively. A strong relationship was observed only between glutathione and Rb contained in PM$_{2.5}$ dust collected from the tram tunnel. More medium-strength correlations can be observed in the case of dusts with smaller fractions, but it can be seen that both PM$_{10}$, PM$_{2.5}$ and PM$_1$ dusts show low correlations between metal content and the loss of antioxidants. This research shows the impact of individual substances contained in dust fractions on human health and the effects caused by toxic substances contained in dust.

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Table 1. Sampling schedule for particulate matter fractions obtained in car tunnel and tram tunnel in Krakow [2].

Fraction	Location	Date	Duration
PM_1	car tunnel	12.04.2016-14.04.2016 19.04.2016-21.04.2016 23.04.2016-24.04.2016	8 days
PM_1	tram tunnel	28.06.2016-04.07.2016	7 days
$PM_{2.5}$	car tunnel	04.04.2016-11.04.2016	8 days
$PM_{2.5}$	tram tunnel	05.07.2016-11.07.2016	7 days
PM_{10}	car tunnel	14.03.2016-18.03.2016 20.03.2016-22.03.2016	8 days
PM_{10}	tram tunnel	12.07.2016-12.07.2016 15.07.2016-18.07.2016	6 days

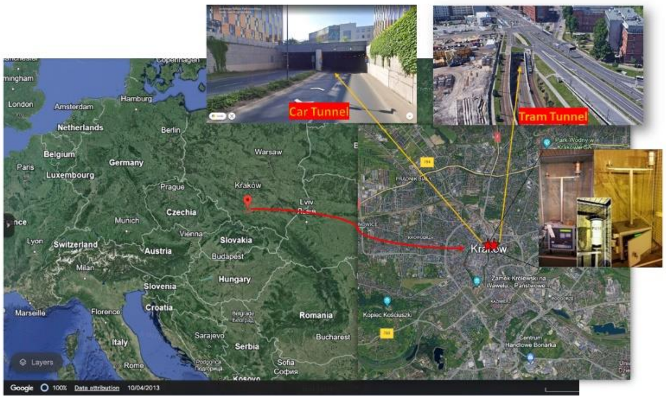

Figure 1. Location of the sampling sites in the city. Inserted photos illustrate the installation of the low-volume air sampler in the road tunnel along with the location of tram and car tunnel.
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AI-Based Data Science: A New Approach for Identifying Trends and Relationships in Environmental Processes

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ABSTRACT

In recent years, the integration of artificial intelligence (AI) in data science has revolutionized the analysis of complex environmental processes. This paper presents a novel AI-based approach for identifying trends and relationships in an example of environmental data, specifically in results of a stove toxicity tests. Leveraging machine learning algorithms, this approach can handle large, multi-dimensional datasets with greater accuracy and efficiency. As many previous studies proved, AI can uncover subtle patterns and interactions that were previously undetectable, providing deeper insights into environmental dynamics []. This methodology enhances predictive capabilities but also aids in the development of more effective environmental policies and strategies. The implications of this research extend to various fields, including ecology, meteorology, and resource management, highlighting the transformative potential of AI in addressing global environmental challenges. Despite challenges and limitations, such as data quality and interpretability of AI models, ongoing research and interdisciplinary collaboration are paving the way for the successful implementation of AI in environmental monitoring, ultimately supporting informed decision-making and sustainable resource management. The study aimed to present the preliminary results of data science with an application of AI predictive models.

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World's first mine air cooling system using ice slurry

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ABSTRACT

In mines equipped with a central air-conditioning system, over time there is a considerable distance between the mining areas and the shafts, which leads to an elongation of the pipelines transporting ice water to the air coolers in the mining areas. Despite thermal insulation, the elongation of pipelines transporting chilled water causes increasing thermal losses, which result in an increase in the temperature of the chilled water supplied to the coolers in the mining areas. If the temperature of the chilled water at the entrance to the coolers is higher than assumed in the technical catalogs, the efficiency of the air coolers decreases and it becomes increasingly difficult to achieve the required air temperature at the mining site. Such a case occurred, among others, in the Bogdanka SA mine, in the Stefanów field. Prior to the expansion, the mine's central air-conditioning system was based on the generation of ice water at a temperature of about 1.5°C on the surface and its transfer through a network of pipelines to air coolers in the mining areas. The water cooled at the Surface Air Conditioning Station (SACS), in the amount of about 264m^3/h, flows through insulated shaft pipelines and further through the PES towards the face and longwall coolers. The return pipeline sends water at a temperature of about 20°C back through the SACS and back through the shaft piping to the SACS.

At the SACS, the return water is again cooled to a temperature of about 1.5°C by means of cooling equipment with open cooling towers and again (in a closed circuit) sent via the PES to the underground cooling consumers on the 990m level. The cooling capacity of this cooling system was about 6MW before the modernization. In order to increase the capacity of the mine's existing chilled water air conditioning system, the flow rate of chilled water in the pipelines would have to be significantly increased. So far, this has been the only way used to increase the cooling capacity of the central plant. Unfortunately, in order for this to be done, it would be necessary not only to expand the SACS, but also to replace the vertical and horizontal water pipelines with larger ones (most of the pipelines are not adapted to the higher operating pressure associated with an increase in the flow rate of chilled water) and to expand the pressure exchanger system (PES) along with the pumping systems. Given that the central air conditioning covers the entire region, such a solution would require a temporary reduction or even a halt in coal mining and would therefore be very costly.

An alternative solution could be the construction of a completely new shaft with infrastructure, a new machine hall, and the development of new vertical and horizontal pipelines and a new PES. Such a solution does not require halting mining, but is in turn time-consuming and also very expensive. Therefore, it was necessary to consider other solutions to the problem of increasing the ability to transport coolant using the existing infrastructure. The design of the new cooling system proposed by WEIP AGH took advantage of the possibility of using water ice, which, in combination with ice water from the existing cooling system, will be the factor transporting "cold" in the mine. This resulted in the world's first mine air cooling system using ice slurry instead of ice water. After the expansion of the system in 2021, the cooling capacity of the installation at the LW Bogdanka SA mine was raised to over 9MW.

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Shell Research Alliance

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ABSTRACT

Shell's scientists, researchers and engineers around the globe are working to develop, deploy and commercialise technologies that are vital in the transition to a low-carbon energy future. In 2023, we spent $1,287 million on research and development (R&D), compared with $1,067 million in 2022. From the total amount invested in 2023, about 49% of the total expenditure was on projects that contributed to decarbonisation in the areas of renewable power, industrial electrification, hydrogen value chain, material science, circularity & bio-feedstock and direct air capture, for example. We also started work on more than 270 R&D projects with universities in 2023, compared with more than 250 in 2022.

Energy Transition Campus Amsterdam (ETCA) is one of the main R&D and technology centres in Shell. It is an open campus, currently hosting more than 20 innovative companies and universities in addition to 1000+ Shell staff continue to learn, develop, and innovate through collaboration, technology, and innovation. The technology solutions that are developed at ETCA include sustainable aviation fuel, 3D imaging and printing, catalysts, green hydrogen, plastic circularity facilities. Through the partnerships with universities, many student interns get the opportunity to be part of industrial projects. ETCA is also an active participant in the European Union funding programs. We are looking for new academic institutions across Europe to join the ETCA.

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The effect of copper(II) salt precursors on HKUST-1 physicochemical properties and removal of trivalent chromium ions from aqueous solutions

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Keywords: metal-organic framework, HKUST-1, adsorption, trivalent chromium

ABSTRACT

Metal-organic frameworks (MOFs) are an advanced class of micro/mesoporous materials characterized by a regular structure. MOFs are composed of organic linker and metal clusters combined by coordination bonds. Owing to a broad diversity of organic linkers and metal clusters, there are above 123000 different structures of MOFs reported in 2024. Due to unique architectures, MOFs possess high porosity, low bulk density, and one of the highest specific surface areas among porous materials up to 7800 $m^2 \cdot g^{-1}$. With such properties, MOFs have gained much attention in recent years as adsorbents, drug delivery carriers, and catalysts [1].

HKUST-1 (Hong Kong University of Science and Technology-1) is a MOF structure obtained by coordination of 1,3,5-tricarboxylic acid (trimesic acid) used as organic linker and copper(II) salt precursor as metal cluster. HKUST-1 is characterized by a pore diameter of 0.9x0.9 nm, specific surface area >1000 $m^2 \cdot g^{-1}$. The synthesis procedure can significantly affect the physicochemical properties of the final product. In a typical synthesis procedure, trimesic acid is being dissolved in organic solvent (dimethylformamide (DMF), ethanol, methanol), while copper(II) salt precursor is being dissolved in water. The solutions are then mixed together and kept by selected time at selected temperature. Mixing, using ultrasounds or microwave assisted synthesis can affect the crystal growth, product yield and its properties.

In this study, we have investigated the effect of copper(II) salt precursors, namely: nitrate, sulfate, chloride, and acetate on the selected physicochemical properties of obtained HKUST-1 MOFs. To allow greener synthesis, trimesic acid was dissolved in ethanol instead of DMF. 9 mmol of copper(II) salt was dissolved in 30 mL of water, while 5 mmol of trimesic acid was dissolved in 30 mL of ethanol. Solutions were then combined and mixed using ultrasound for 15 min. Next, the solutions were placed in an electric heated oven at 110 °C and kept without stirring for 24 hours. The obtained products were filtrated and washed several times with water to remove unreacted reactants. Air-dried products were then dried in oven at 110 °C for 4 hours, followed by vacuum drying at 80 °C for 20 hours. Dry products were collected for further analyses.

Copper(II) salt precursors significantly affected the properties and yield of products. Synthesis using copper(II) chloride yielded no product after 24 hours. Copper(II) acetate allowed ultra-fast nucleation after mixing the initial solutions together. From the XRD patterns, it was evidenced that the structure of HKUST-1 was obtained for syntheses with nitrate, sulfate and acetate (Figure 1a). However, for synthesis with copper(II) acetate, additional phases were recorded originating probably from $Cu_2OH(BTC)(H_2O)_n \cdot 2nH_2O$ as was also reported in the literature [3]. The specific surface area of obtained HKUST-1 MOFs was strictly copper(II) salt precursor dependent and change in order: acetate (553 $m^2 \cdot g^{-1}$),

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sulfate (937 $\mathrm{m^2\cdot g^{-1}}$), and nitrate (1153 $\mathrm{m^2\cdot g^{-1}}$). From the FTIR spectra (Figure 1b) it can be seen that HKUST-1 obtained from both copper(II) nitrate and sulfate were comparable, whereas HKUST-1 from copper(II) acetate exhibited additional peaks in the 3250-3700 $\mathrm{cm^{-1}}$ region, implying occurrence of OH groups loosely bonded to the MOF structure. From the Dynamic Light Scattering (DLS) (Figure 1c) it can be seen, that the particle size displayed 2 maxima, which are consistent with the crystallite sizes as obtained from SEM images (Figure 1d-f). Copper(II) salt precursor also affected the morphology and shape of the HKUST-1 crystallites – bipyramids from copper(II) nitrate and sulfate (Figure 1d,e), and boards from copper(II) acetate (Figure 1f).

HKUST-1 MOFs were evaluated as potential adsorbents of Cr(III) ions from aqueous solutions [4]. Freundlich and Langmuir isotherm models (for adsorbent dose of 0.5 $\mathrm{g\cdot L^{-1}}$) were correlated with the experimental data implying better coefficient of Langmuir model - suggesting that the adsorption was monolayer, with potential ion exchange between Cu(II) and Cr(III) ions. Adsorption capacity varied in order: acetate (79 $\mathrm{mg\cdot L^{-1}}$), sulfate (102 $\mathrm{mg\cdot L^{-1}}$), and nitrate 154 ($\mathrm{mg\cdot L^{-1}}$).

To conclude, HKUST-1 MOF is a material whose properties can be controlled by changing the synthesis parameters. Its potential application as Cr(III) ions adsorbent was confirmed. Further regeneration studies can bring valuable information on its potential application for wastewaters treatment.

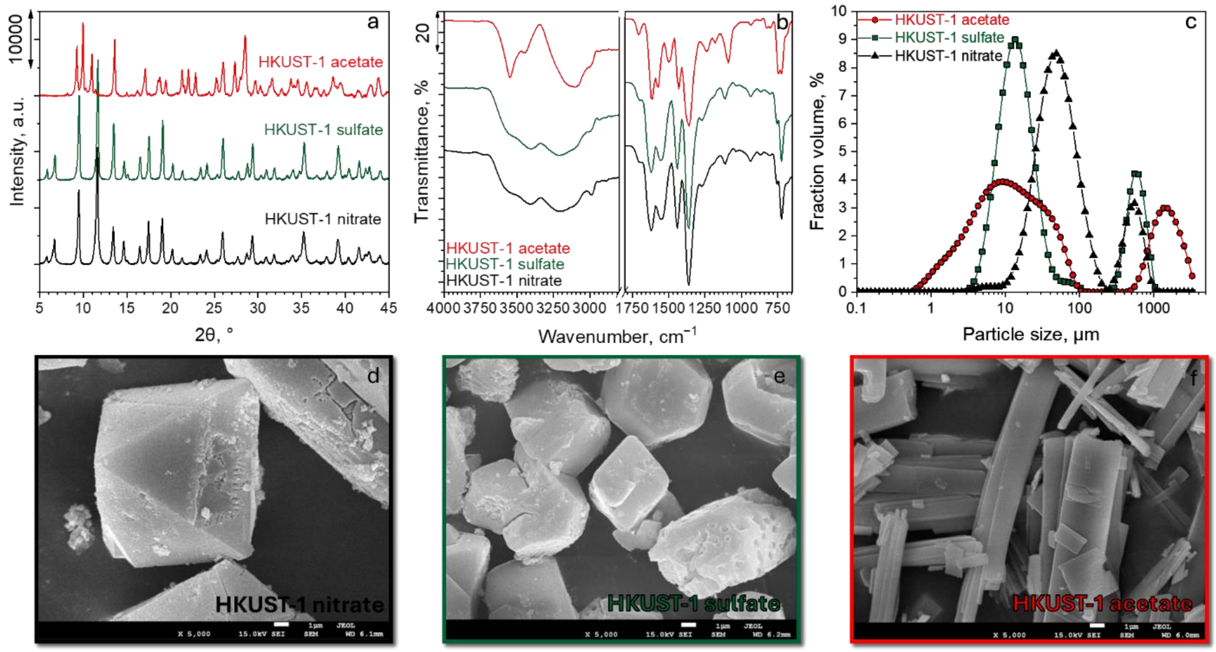

Figure 1. XRD pattern (a), FTIR spectra (b), DLS (c), SEM images (d-f) of investigated MOFs.

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Germany's Delayed Nuclear Phase-Out: Insights from the 2022/23 Energy Crisis

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Keywords: nuclear phase out, energy crisis,

ABSTRACT

The nuclear phase-out, a cornerstone of the German energy transition, was revised during the 2022 energy crisis. Due to the risk of shortages in the gas supply, the federal government postponed the phase-out by three and a half months. Consequently, the last three German nuclear power plants continued operating with remaining fuel elements until April 15, 2023, instead of shutting down at the end of 2022. This date marks the end of the nuclear era in Germany, as per the 19th Amendment of the Atomic Energy Act (19. AtGÄndG). The postponement of the nuclear phase-out aimed to enhance energy supply security, aligning with national goals and the European Commission's efforts to reduce gas consumption. The presentation at the EFE 2024 conference will discuss the impacts of this of the nuclear phase-out postponement on the German and European electricity markets and power systems.

Methods

Using the electricity market model ELTRAMOD and the grid optimization model ELMOD [2], the study reproduces historical market dynamics and grid flows during the extension period (January 1 to April 15, 2023) and compares them to the counterfactual scenario without postponing the nuclear phase-out. The study focuses on three primary aspects: the security of supply, particularly in terms of reduction in gas-fired power generation amid looming gas shortages; the economic impact, including the effect of the nuclear phase-out postponement on prices and the welfare of European countries; and systemic considerations related to the capacity of German nuclear power plants (NPP) and the generation mix in the integrated European market with a high share of renewable energies (RE). Various weather years and scenarios with the reactivation of nuclear power plants in Germany are examined to generalize the results for 2023 and provide insights into the complex interplay of energy policy decisions, market dynamics, and the evolving energy landscape in Germany and Europe.

Results

The results show that the extension of the operating period of the last three nuclear power plants in Germany in the so-called stretching operation reduced the average electricity price in Germany by almost 9 euros per MWh compared to the counterfactual scenario of the planned phase-out at the end of 2022. Germany saved almost 10% of its electricity production from gas, equivalent to 1.6 TWh, with the rest of Europe saving an additional 1.3 TWh. Welfare increased in all European countries in the model, although some countries recorded significant losses on the producer side, as the postponement of Germany's nuclear phase-out reduced its import demand. The last three nuclear power plants, could have further reduced grid congestion the main bottlenecks in the German Transmission grid, if they could have operated without the constraints due to the limited period of the postponement. However, the scenario with six nuclear power plants shows the highest number of overloaded lines and the highest curtailment of renewable energies. In this scenario, renewable energy plants were curtailed more frequently due to the higher feed-in from nuclear power plants in the northwest. Overall, this scenario with maximum nuclear power capacity in Germany performs the worst in terms of the economic efficiency of renewable energies and flexible power plants.

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Summary

Using a linear optimization market model and a grid model for the European power network, the multifaceted impacts of the German government's decision to extend the operation of the last three nuclear power plants in the so-called stretching operation were investigated. The postponement of the nuclear phase-out was a pragmatic decision amid the energy crisis of 2022-2023. Without the last three nuclear power plants, the average electricity price in the first quarter of 2023 in Germany would have been about 9 euros per MWh higher, and Germany and Europe would have been more reliant on coal and natural gas for power generation. The need for positive and negative redispatch for grid congestion management would have also increased. The positive impacts of the delayed nuclear phase-out would have been even greater if the power plants had more preparation time to ensure higher availability of their capacities.

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Where does hydrogen come from?

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Keywords: hydrogen, hydrogen production methods

ABSTRACT

Synthetic information about the distribution of hydrogen in the Universe, on Earth in free and chemically bound form is presented. Different technologies for obtaining hydrogen as an energy feedstock, and a raw material for technological purposes were commented. Chemical, electrochemical, thermochemical, photochemical, and biological methods were included. Scale of opportunities and prospects of hydrogen use in the economy have been analyzed. Poland's position among the countries producing and using hydrogen was indicated. Additionally, the possibility of free hydrogen obtaining using methods known from the extraction of fossil fuels was indicated. Relevant examples have been presented. For selected hydrogen obtaining methods the level of related greenhouse gas emission was indicated

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ENERGY FUELS ENVIRONMENT EFE2024
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Use of Thermally Conductive Adhesives in Composite Sorbent Beds for Adsorption Refrigeration Applications

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Keywords: Thermally Conductive Adhesives, Composite Sorbent Beds, Adsorption Chillers, Sorption Capacity

ABSTRACT

The contemporary increase in cooling demand is an extremely dynamic phenomenon, directly resulting in a growing number of installed cooling devices [1]. This trend is primarily influenced by climate change, including global warming, which manifests as rising average temperatures on Earth and more frequent and extreme temperature values. Additionally, ongoing urbanization and economic development contribute to the intensive growth of the refrigeration and air conditioning sector [2]. In response to these challenges, intensive research is being conducted on alternative cooling technologies. One promising solution is cooling based on the sorption phenomenon. In particular, adsorption chillers powered by low-temperature heat in the range of 50–90 °C present an interesting alternative to conventional cooling devices. However, the main challenge of these systems is the low efficiency of heat transfer between the heat exchanger area and the adsorbent.

The aim of this research is to evaluate the potential of using composite bonded beds with thermally conductive binders to improve thermal conductivity while maintaining sorption capacity. Utilizing such beds can significantly reduce thermal resistance at the heat exchanger-adsorbent contact area, potentially increasing the efficiency of the entire cooling system and allowing for the use of a lower temperature desorption medium. Improving heat transfer efficiency in adsorption cooling systems can open new possibilities for environmentally friendly and economical cooling, which is crucial in the context of growing cooling demands and global climate change.

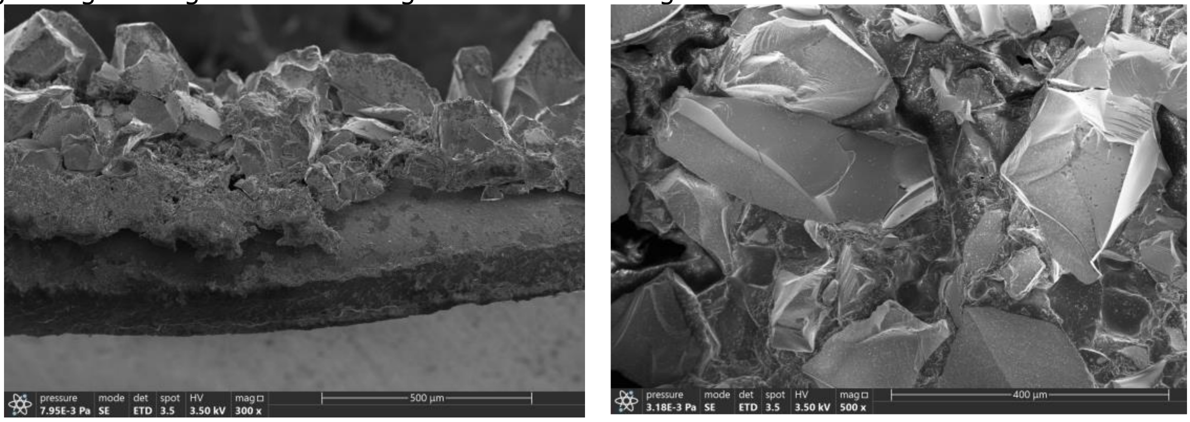

Figure 1. SEM images of narrow-pore silica gel with a granulation

Various thermally conductive binders, such as adhesives based on epoxy resin, polyvinyl alcohol, and cellulose, were analyzed, focusing on their application potential and tendency to form durable connections without significantly reducing the porosity and sorption capacity of composite beds. The selected binders were doped with copper to improve the thermal conductivity coefficient. Samples were made using a two-step bonding

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technology: in the first step, an appropriate amount of binder was applied, and in the second step, the chosen adsorbent was added. Additionally, the possibility of applying a specific thickness of the sorbent was analyzed to optimize the bonding process.

The sorption capacity and sorption kinetics were measured in a vacuum using a DVS Vacuum apparatus. The sorption properties of wide-pore and narrow-pore silica gels were analyzed for different granulations in the range of 200-1000 µm and at temperatures of 30, 50, and 70 °C to select the best materials for further research. The thermal conductivity coefficient was measured using methods based on unsteady heat flow: THW (transient hot wire) and TLS (transient line source), to compare research results in the temperature range of 20-60 °C.

Additional studies were also conducted for the selected samples. Fourier-transform infrared spectroscopy (FTIR) was performed on the raw materials, binders, and coated samples to examine their chemical composition. Scanning electron microscopy (SEM) was used to obtain detailed images of both raw and coated samples in various planes, complemented by chemical composition analysis. Thermogravimetric analysis (TG) and differential scanning calorimetry (DSC) were carried out on selected materials to determine the thermal stability of the binders.

The results indicate that it is possible to create bonded sorbent beds with a specific binder thickness and strong adhesion between the binder and the coated element, as shown in Figure 1. The use of thermally conductive binders can improve the thermal conductivity of the sorbent beds by up to 21.2% (Figure 2) without significantly reducing the sorption capacity. This approach offers a promising solution for enhancing heat transfer in adsorption-based cooling systems, potentially leading to more efficient and effective devices.

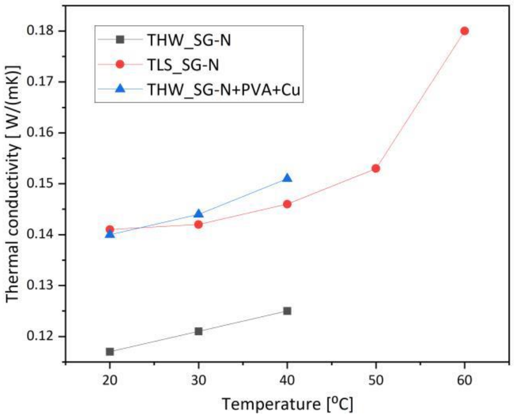

Figure 2. Change in thermal conductivity coefficient with temperature depending on the material and the applied research method.

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Innovative Heat Exchanger Fins for Adsorption Chillers: Design and Simulation

Piotr Boruta[1]*, Wojciech Kalawa[1], Łukasz Mika[1], Karol Sztekler[1]

Keywords: Adsorption Chillers, Heat Exchanger Simulation, Fins Geometry, Adsorption-Desorption Kinetics, Model Validation

ABSTRACT

The primary objective of this study is to develop a novel heat exchanger design and optimize the geometry to reduce desorption time, thereby enhancing the Coefficient of Performance (COP) and Specific Cooling Power (SCP) of adsorption chillers. The research focuses on simulating heat exchangers in porous media, exploring new fin geometries, and simulating the heating of fins and inter-fin spaces during desorption. Additionally, the study includes simulations of adsorption and desorption kinetics using the Linear Driving Force (LDF) and Dubinin-Astakhov (D-A) models.

Experimental data for model development and validation were obtained from macroporous silica gel samples using the DVS vacuum apparatus, which allows continuous monitoring of sample mass changes during adsorption and desorption with high sensitivity (0.1 µg). The instrument maintains temperature stability at 25°C (±0.02°C) and humidity within ±0.1% of the target value. Measurements were performed under low vacuum conditions, reflecting the operational environment of adsorption cooling systems.

The methodology included pre-drying and degassing the samples by heating them to 100°C for 60 minutes, followed by temperature stabilization for 1 hour. The adsorption process was analyzed in 10 steps (20 minutes each) over the P/P0 range of 10–100%, and then P/P0 was gradually decreased to 10% in 10 steps, each lasting 20 minutes. Adsorption and desorption isotherms were calculated based on experimental results, and the entire measurement cycle was repeated twice to ensure sample stabilization and analysis.

In this study, six fin geometries were compared (illustrations are provided in Figure 1). Each analyzed geometry has the following main dimensions: fin width of 30 mm, fin height of 100 mm, HTF tube hole diameter of 20 mm, and base plate thickness of 0.5 mm. Additional ribbing of the heat exchanger fins was analyzed in the form of fins perpendicular to the base plate plane, fins set at an angle relative to the base plate, and fins in the form of cylindrical segments.

The simulation was divided into the following stages:

1) Heating simulation of the fin assuming no heat removal from the fin:
    - The wall in the plane of the HTF tube hole axis was assumed to be symmetrical.
    - The HTF tube hole wall was set at a constant temperature (50°C, 60°C, 70°C).
    - The remaining walls were set as adiabatic.
    - The average temperature change of the fin surface was studied.
    - This stage was used to validate the prepared 3D model of the fins to select the appropriate degree of simplification to generate the appropriate computational grid.
2) Heating simulation of the inter-fin space:
    - The inter-fin space was assumed to be a porous zone to accurately capture heat transport in the porous structure composed of adsorbent grains and dry air.
    - A fin-silica gel-fin-silica gel-fin arrangement was used, where the external fins
    - A symmetry condition was imposed on the resulting wall, and a convection condition was imposed on the remaining walls (the arrangement is shown in

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[1]

the illustration).

3) Desorption simulation:
   - The computational grid from the previous stage was used, and an initial outlet condition was added on the boundary walls of the inter-fin space with the adsorption chamber volume.
   - Additionally, a user-defined function (UDF) was implemented to account for the desorption process, including sorption kinetics using the LDF model and determining the adsorption potential at each time step using the D-A model.
   - The model constants were determined based on preliminary experimental results.

The prepared sorption model gives a good representation of the experimental results, achieving an RMSE of 2 and an R^2 of 0.98. This research aims to provide insights into the optimization of heat exchanger designs for adsorption chillers, potentially leading to significant improvements in their performance. The findings are expected to contribute to the advancement of adsorption cooling technology by validating the LDF and D-A models using gravimetric analysis results from vacuum DVS experiments.

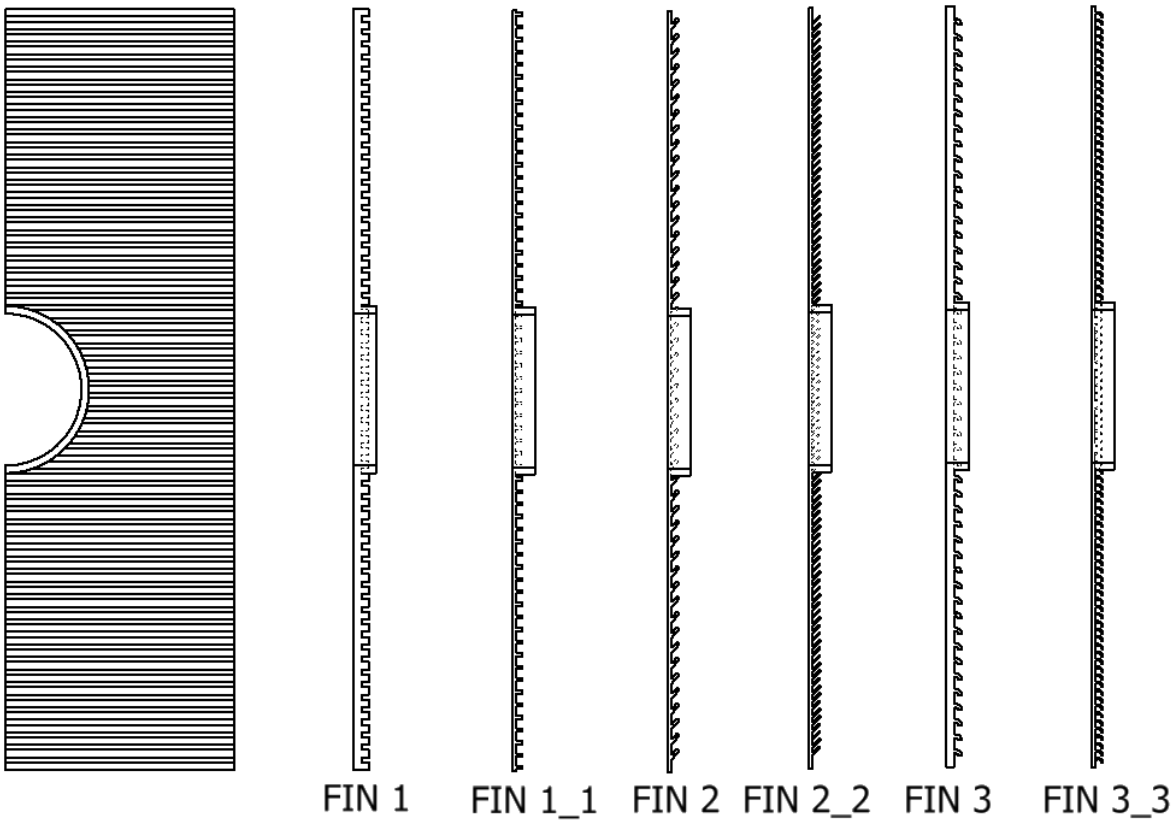

Figure 1. Analysed Fin Geometries

General overview of hydrogen technology and utilization its in gas turbines

Artur Harutyunyan[1]*, Krzysztof Badyda[2], Łukasz Szabłowski[2]

ABSTRACT

To align effectively with the Paris Agreement's goal of achieving a carbon-neutral economy by 2050 and to robustly mitigate anthropogenic climate change, it is crucial to significantly boost the share of renewable energy generation while simultaneously ensuring energy security and enhancing energy efficiency.

Hydrogen and hydrogen-based fuels can play an important role in the decarbonization of sectors where emissions are hard to abate and alternative solutions are either unavailable or difficult to implement, such as heavy industry and long-distance transport. Hydrogen technology, particularly in the context of gas turbines, offers a promising pathway towards a more sustainable and decarbonized energy system. While there are technical and economic challenges to address, ongoing advancements and increasing interest from industry and government are driving the transition towards hydrogen as a viable energy carrier. The integration of hydrogen into gas turbines not only leverages existing infrastructure but also paves the way for a cleaner, more resilient energy future. Amidst the global energy crisis, the gas turbine industry has made notable progress in developing turbines that can operate solely on 100% hydrogen by 2030. These developments heighten the urgency to delve deeper into the study of hydrogen-powered gas turbines and their complex systems.

In this work, a general overview of hydrogen technology and its utilization in gas turbines is presented. Additionally, energy and exergy analyses for an exemplary gas turbine were conducted to demonstrate the behaviour of hydrogen or methane-hydrogen fuel mixture powered gas turbines.

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Analysis of the content, composition, and structure of microplastics found in sewage sludge

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Keywords: microplastic, sewage sludge, soil, spectroscopy, environmental pollution

ABSTRACT

Microplastics (MPs) are plastic particles whose size does not exceed 5 mm[1]. We distinguish two type of microplastics: primary microplastics, which are intentionally added to products such as cosmetics and hygiene items[1], and secondary microplastics, which result from the breakdown of larger plastic debris through various physical factors, such as friction, chemical processes like decomposition under radiation, and biological degradation by bacteria[1,2]. Research mainly focuses on the marine environment, where microplastics directly threaten plants and animals[3]. Much less research focuses on analyzing microplastics in the soil or atmosphere. The circular economy aims to minimize waste and maximize the use of resources. For this purpose, sewage sludge is used to produce fertilizer [4]. Processed sewage sludge from sewage treatment plants is used for its nutritional content and soil fertilization. However, it should be noted that the sludge may contain harmful substances such as heavy metals, pharmaceuticals and their residues, and microplastics [4]. The study aimed to analyze sewage sludge samples in terms of quantitative and qualitative analysis of microplastics.

Samples from May, June, and July 2021 were tested. The sewage sludge was first freeze-dried, and then the same masses were flooded with hydrogen peroxide to eliminate the matrix. In the next step, the samples were density-separated using a saturated calcium chloride solution. The separated fractions were counted and qualitatively examined using ATR FTIR, and additional photos were taken using a confocal microscope (Fig.1). The structure of the samples was examined using scanning electron microscopy (SEM) (Fig.2).

The average content of MPs in these months was 2942, 2341, and 1746 fragments per 100 grams of the dry weight of stabilized sewage sludge, respectively. Fragments dominated in each sample. The most common polymer in the stabilized sewage sludge was low-density polyethylene. During structural analysis, the microplastic particles showed high porosity (Fig.2).

Figure 1. Photo of microplastics taken on a confocal microscope

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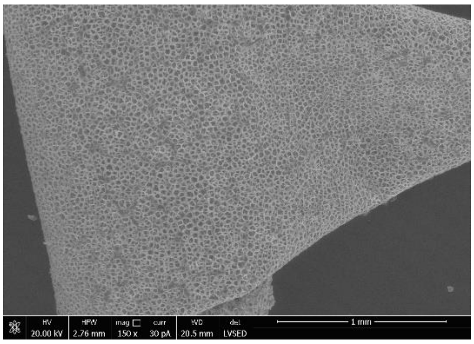

Figure 2. SEM image of the microplastic structure

Research has confirmed the high risk of re-emission of MPs into the environment by stabilized sewage sludge and fertilizers produced from it. The experiment showed the use of fertilizer made from sewage sludge may result in the release of 6110 to 13 889 microplastics per 1 m^2 of soil. The porosity of the samples shows that they can also adsorb other substances on their surface, including heavy metals and pharmaceuticals.

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Forecasting Sectoral Electricity Consumption in the Selected EU Countries: A Comparative Analysis of Time Series Models

Atif Khan[1],*, Artur Wyrwa[1], Maciej Raczyński[1]

Keywords: Electricity consumption, Forecasting, SARIMA, Machine Learning, Deep Learning, Disaggregated electricity

ABSTRACT

Electricity empowers human societies through its central role in water and natural gas supply, transportation and traffic systems, ventilation and lighting of buildings, industrial and agricultural production, communications, and security systems [1]. A compelling case for the significance of electricity load forecasting is made by electricity's enormous impact on societal health, economic growth, energy security, and sustainable development [2]. Precise load forecasting can provide a stable and uninterrupted power supply and aid energy planners in making more intelligent decisions [3]. Conversely, inaccurate load forecasting could result in miscalculations of the electrical supply and demand balance, which could have catastrophic effects like blackouts. For instance, research indicates that in 1984, a 1% inaccuracy in load prediction cost the United Kingdom 10 million pounds [4]. Forecasts of sectoral electricity consumption (SECs) are vital resources for policymakers in developed and developing countries. It is generally known that the SEC forecasting model plays a crucial role in reducing energy use, changing industry behaviors, and establishing more efficient energy management strategies. It is vital to examine the prediction of future energy consumption based on time series data and other characteristics, which depict the dynamics of different energy sources used in electricity consumption. This encourages researchers to use historical time series data and appropriate estimation techniques to create effective SEC forecast models. The current study has extracted Eurostat's time series data from 1990–2022 on sectoral electricity consumption, and the data set is based on annual and monthly observations. To forecast SEC in the selected EU countries, the study uses a comparative analysis of time series models, particularly the seasonal independent integrated motion average (SARIMA) model and the machine learning model based on LSTM neural networks. Although the ARIMA model is a simple method with many applications, it relies heavily on assumptions about the linearity of historical data and the nature of errors. The foundation of ARIMA models is the presumption that the data exhibits trend, seasonality, auto-correlation, and non-stationarity as characteristics of internal structure. Hochreiter initially suggested the Long Short-Term Memory (LSTM) deep neural network technique, an RNN variant [5]. Among deep learning-based methods for time series forecasting, LSTM is famous for being influential [6]. By storing the forward and backward-propagated weights in its layers, the Long Short-Term Memory (LSTM) performs better while learning both short- and long-term dependencies. LSTM is more adept at predicting time series, such as electrical load, when considering time delay memory cells[2]. Long-term dependency issues are avoided by LSTM networks, which can forecast short- and long-term time series with negligible error[3]. Being flexible and automatic in learning is another crucial feature of LSTM, which facilitates the simple processing of large amounts of data[4].

The study aims to predict sectoral electricity consumption at aggregate and non-

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aggregate levels, as it is crucial to analyze the differences between the consumption of electricity from non-renewable energy and renewable energy across sectors. It provides a broader picture for policymakers to examine the exact supply and demand for sectoral electricity from renewable energy, which is cleaner, safe, sound, and environmentally friendly. This study is crucial for forecasting sectoral electricity consumption at aggregate and aggregate levels, suggesting policy recommendations for adopting the 2030 SDGs goals, and providing a solid base to compare our empirical findings with the EU scenario until 2020-2025. The study provides a base for an analysis of future forecast scenarios for the growth of renewable energy. These conclusions enable the formulation of global policy recommendations in the energy market and regulatory frameworks.

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Novel water-gas shift catalyst for lean steam to gas ratio applications

Katarzyna Antoniak-Jurak, Paweł Kowalik, Kamila Michalska, Anna Mrozek

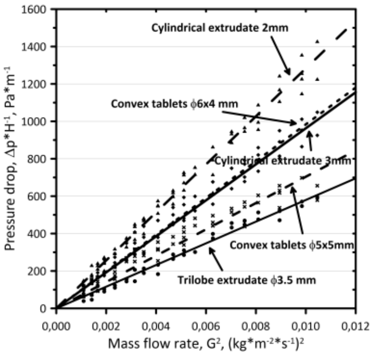
Keywords: hydrogen, water-gas shift, Cr-free catalyst

ABSTRACT

Catalytic water-gas shift (WGS; $CO+H_2O \rightleftarrows H_2+CO_2$; ΔH_{298K}=-41 kJ·mol^{-1}) is the one of key processes of industrial scale H_2 production from natural gas or refinery residuals reformates. Growing hydrogen demand contributed to the renewed interest in WGS reaction and efficient, eco-friendly catalysts for hydrogen generation processes prepared by convenient routes. Among variety of compositions developed for low- and high-temperature shift reaction, special attention was given from decades to find and develop of Fe and Cr-free systems being efficient alternatives for widely applied conventional Fe-Cr-Cu catalysts [1].

The present study is focused on evaluation of novel Cr-free ZnAl-oxide based catalyst at high-temperature WGS conditions. XRD, BET and microscopic techniques were used to characterize the physicochemical features of the catalysts. The comparative activity measurements were carried out using Tiomkin-type differential reaction at the pressure of 2.5 MPa and wide range of temperature and steam to carbon molar ratio. Finally, the material of optimal catalytic properties was formed into functional form, meeting the requirements of industrial reactors.

It was shown that extrusion technique is an efficient method to form the catalytic material into grains of a high geometric surface area per unit volume of the bed (Fig. 1). Pressure drop comparative measurements revealed beneficial properties of trilobe extrudates providing beneficial hydrodynamics properties of the catalyst bed (Fig. 2).



The catalysts exhibit high and stable activity and their selectivity is significantly higher than that of conventional HT-WGS catalysts. Both at typical and under decreased H_2O/C molar ratios, no methane formation was observed under HT-WGS conditions over the novel catalyst.

Specific alkali-promoted ZnAl-oxide catalyst method containing no toxic, carcinogenic or environmentally hazardous substances demonstrated beneficial activity and selectivity at favorable technological HT-WGS conditions (i.e. at lower steam to carbon ratios). Moreover, one may anticipate that it is possible to produce the catalyst simply and efficiently on a large scale at relatively low costs.

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ArcelorMittal Poland – steel production and sustainable development

Piotr Żarczyński[1], Czesław Sikorski[1], Piotr Drzystek[1]

ABSTRACT

The goals of the European Green Deal encompass the gradual reduction and eventual elimination of GHG emissions. This initiative inspires steel producers to undertake actions leading to the implementation of the modern solutions allowing them to be aligned with the targets. It requires a complete change of steel production technology which can bring a net zero balance of GHG emissions. Simultaneously, steel producers must remain competitive in the global steel market. It seems to be extremely difficult in a situation where market rivals are not bound by the same rules. It means that the new technology should also bring technological advantages resulting in economic benefits. Consequently, transformation of steel production seems to be extremely demanding and difficult and has to be conducted in a relatively short time. Additionally, the fast-changing and unpredictable geopolitical situation and associated risks compel steel producers to actively and quickly adapt and optimize their chosen path of technological development, even during its implementation.

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Environmental and industrial mercury measurements

Jerzy Górecki[1], Mariusz Macherzyński[1], Janusz Gołaś[1]

ABSTRACT

Presentation describe the results of work related to projects, construction and research, conducted under the supervision of prof. Janusz Gołaś, whose purpose was the following:

(1) the creation of reliable analytical instruments for the research in the processes of emission of mercury derived from the combustion and processing of coal,

(2) the support of activities whose purpose is to reduce the level of anthropogenic emission of mercury,

(3) the study of the environment-related results of this emission.

The construction-related work and research, may be divided into three groups. The first group are works which describe measurement and auxiliary systems, as well as analytical procedures which serve the purpose of measuring of concentrations of mercury and their forms in exhaust gases (the power industry) and in processing gases (the coke industry). The second group describes instruments which support the activities whose purpose is to reduce the level of the emission of mercury to the environment – the research in the process of low-temperature pyrolysis and the testing of sorbents for the removal of mercury from exhaust gases. The third group comprises works which describe measurement systems and the research which was conducted owing to these instruments, whose purpose was to evaluate the environment-related results of the emission of mercury (the research in the level of methylmercury in the organs of selected animals).

The following was the result of the project-, construction- and research-related activities:

– a mobile system for the research in the speciation of mercury in exhaust gases [1],

– a low-pressure, ultrasonic calibrator of mercury Hg^{2+}[2],

– a system for the acquisition of samples of purified coke gas [3],

– a system for the testing of coals in reference to the thermal removal of mercury from the said coals [4],

– a laboratory generator of exhaust gases (an element of the system for the testing of sorbents) [5],

– the PDMS-GC-AFS system for the determination of methylmercury in biological samples [6],

– the semi-automatic Tenax-CG-AFS system for the determination of MeHg in biological samples [7].

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ENERGY FUELS ENVIRONMENT EFE2024
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Research on material properties and use of composite tanks manufacturing technology for compressed hydrogen storage

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Keywords: composite tank, type IV tank, hydrogen, hydrogen storage, energy storage

ABSTRACT

High-pressure composite tanks for compressed gases, including compressed hydrogen, are widely used in various industries. A study on material characteristics and manufacturing technology for composite tanks intended for compressed hydrogen storage was conducted as part of the completed project "Development of technology for the production of ultra-light composite hydrogen storage tanks for distributed energy systems”.

This project focused on the production of type IV tanks featuring an external composite structure made of high-strength fibers and hardenable resin, combined with an internal liner made of thermoplastic polymer. The developed composite tanks are intended for use in the automotive, aerospace, and mobile and fixed storage bundle industries.

The project resulted in the development and prototype production of type IV composite tanks with capacities of 1.2L, 6.8L, 120L, and 195L, designed to store compressed hydrogen at pressures of 350 and 700 bar. The industrial research, experimental development, and pre-implementation work included research on raw materials, the development of new material formulations, and the technological parameters of thermoplastic polymers with enhanced barrier properties. Additionally, research was conducted on internal tank liners (hydrogen permeability, blistering monitoring), and an innovative process for winding tank fibers was developed, incorporating additional reinforcement with carbon nanotubes.

The work achieved high levels of tightness and barrier properties for the tanks, ensuring the secure storage of hydrogen under high pressure. An optimized structure for the fiber braid and a matrix made of epoxy resin modified with nanoparticles were developed, meeting the strength requirements for 700 bar standards.

As a result of the scientific research and implementation efforts, the composite tanks have significantly reduced weight, very low hydrogen permeability, and maintain the purity of the stored hydrogen. The manufactured tanks are corrosion-resistant and exhibit high operational safety and a longer service life compared to other tank types. These features enable the use of the manufactured tanks in distributed energy systems.

The achieved technical and operational parameters of the cylinders, along with the implementation of new technology for producing composite hydrogen tanks for distributed energy systems, have provided a significant competitive advantage on a global scale.

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ENERGY FUELS ENVIRONMENT EFE2024
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Development of Climate Scenarios For the Małopolska Voivodeship

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Keywords: regional policy, climate neutrality, climate scenarios, greenhouse gas reduction, Małopolska

ABSTRACT

The Małopolska Voivodeship was the first region in Poland to develop and adopt the "Regional Action Plan for Climate and Energy". The aim of this plan is to achieve climate neutrality by 2050 and to implement climate adaptation actions. Currently, work is focused on updating the plan in order to optimize the assumptions and actions set in 2020.

The main goal of the work carried out at AGH was to develop and analyse development scenarios for the Małopolska Voivodeship in the period 2020-2050, in order to determine the optimal investment plan to achieve climate neutrality by the voivodeship. In the frame of work four scenarios were developed:

1. Stagnation - a scenario assuming the lack of implementation of climate goals, in which renewable energy sources and energy efficiency are not promoted.
2. National – a scenario assuming in 2030 reduction of CO_2 emissions for non-ETS sectors by 7% compared to the level in 2005.
3. Małopolska - a scenario assumes the reduction of greenhouse gas emissions by 40% by 2030 compared to 1990 and the achievement of climate neutrality in the voivodship by 2050.
4. Optimistic - a scenario assuming a reduction of greenhouse gas emissions by 55% by 2030 compared to 1990, following the assumptions of the "Fit for 55%" package, including the achievement of climate neutrality of the voivodship by 2050.

The scope of modeling covered the following sectors: extraction, transformation and distribution of energy carriers, generation of electricity and district heat, households, tertiary, transport (road and rail), industry, waste management and agriculture. CO_2 absorption by forests was also considered.

The following conclusions can be drawn from the research:

1. In the stagnation scenario in 2050 65% of the electricity demand will be covered by import because production in fossil fuel power plants will be unprofitable and renewable energy sources will not be well developed.
2. The potential of renewable energy sources is insufficient to ensure the self-sufficiency of the voivodeship. In the optimistic scenario, despite the fully utilized use of renewable energy sources, they manage to cover approximately 45% of the demand for electricity and energy self-sufficiency of voivodship can be achieved, for example, by introducing SMR.
3. It is possible to achieve climate neutrality without reducing the number of livestock and without changing the cultivation of fields.
4. Investment costs incurred by the energy sector are lower than by the household or industrial sectors. In optimistic scenario the cumulative investment cost in the years 2025 -2050 is 61.5, 72.1 and 94.1 billion PLN`2020 for energy, household and industry sectors, respectively.

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Cryptomelane (K-OMS-2) enriched with copper as efficient catalysts for toluene combustion

Jakub Mokrzycki[1,*], **Maciej Guzik**[2], **Joanna Kryściak-Czerwienka**[2], **Dorota Duraczyńska**[2], **Robert Karcz**[2]

Keywords: cryptomelane, manganese oxides, toluene combustion

ABSTRACT

Cryptomelane (K-OMS-2) is a type of tunnelable structure of manganese oxide octahedral molecular sieve. Potassium ions are located inside the pores of 0.46 nm size. It forms rod-like structure, which is dependent upon the synthesis parameters. K-OMS-2 is characterized by high catalytic activity in oxidation reactions owing to lattice oxygen delivery [1].

Toluene is a model VOC (volatile organic compound), which removal via adsorption or oxidation has been intensively studied in recent years [2]. Catalytic combustion is an efficient method for removal of VOCs from industry.

In this study toluene combustion was studied over K-OMS-2 catalytic systems enriched during the synthesis of cryptomelane with 3 different doses of copper(II) nitrate. The phase composition of all samples was compared by means of XRD (Figure 1a). The structure of cryptomelane was maintained for all investigated systems regardless of the increasing dose of copper introduced into the K-OMS-2. Also, the FTIR spectra (Figure 1b) showed no significant changes of the molecular bonds within K-OMS-2 after modification. Addition of copper into the K-OMS-2 framework, have however influenced the toluene combustion profile (Figure 1c). Sample with the lowest dose of copper (Cu1-K-OMS-2), shifted the T50 and T90 (temperatures of 50, and 90% conversion, respectively) towards lower temperature values (by about 10 °C). By increasing the dose of copper (samples Cu2-K-OMS-2, and Cu3-K-OMS-2), this effect was rather negligible and the combustion profile was familiar to the parent K-OMS-2 without copper addition.

To conclude, small addition of Cu into K-OMS-2 structure can enhance the oxygen mobility, which can improve the combustion efficiency of the material [3].

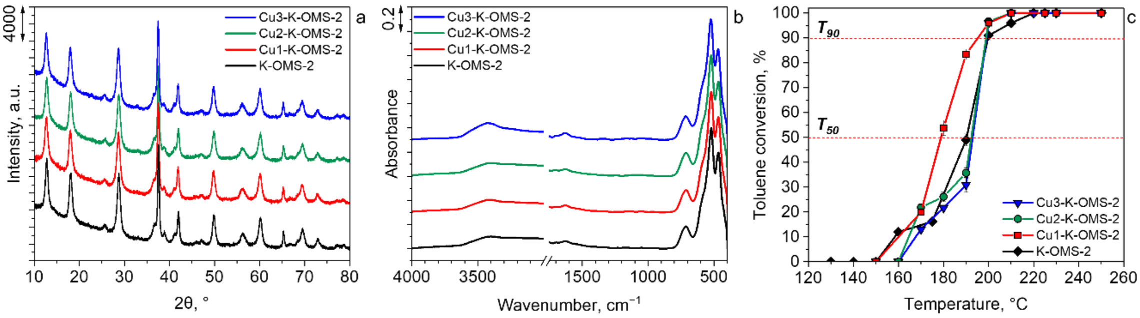

Figure 1. XRD pattern (a), FTIR spectra (b), toluene combustion profiles (c) of investigated K-OMS-2 materials.

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Transition of Energy-Intensive Industries and Regionalization of their Hydrogen Demand

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Keywords: Hydrogen Demand, Industrial Processes, Defossilization, Regionalization, Hydrogen Infrastructure

ABSTRACT

The transition from conventional production technologies to hydrogen-based and electrified industrial production processes is a huge lever towards the EU's declared goal of climate neutrality. However, this transition will only take place if it is economically feasible. While the current discussion provides insightful and detailed analyses of the potential future energy demand (see e.g. for future hydrogen demand [1], [2]), a discussion on the drivers for the industrial technology shift is only beginning (see e.g. [3]). An important incentive to switch to low-carbon technologies is the price of CO_2 emissions. The CO_2 price-driven changes in industrial production technologies imply shifts in energy demand, and thus affect infrastructure requirements. While the German electricity grid is continuously maintained and expanded, the development of the hydrogen infrastructure is still in its infancy.

In this study, we aim to determine the expected hydrogen demand under certain scenario assumptions and to conclude on the hydrogen infrastructure requirements. To this end, we derive industrial process-specific technology pathways based on scenarios with different CO_2 and energy prices. Specifically, we determine the technology-based cost of CO_2 abatement, which allows us to identify the least-cost means of production (be it maintaining conventional production, direct electrification, or switching to hydrogen) for the given scenario framework. Assuming that industry will with certainty choose the least-cost means of production, we derive the resulting national energy demand for the pre-defined production volumes for the industries considered. Finally, we regionalize the national energy demand based on site-specific data in order to assess the infrastructural implications of the industrial transition.

Our analysis is based on a two-step approach. First, we estimate the energy demands of energy-intensive industrial processes for the defined scenarios using a bottom-up model. This model identifies the least-cost production technologies based on the techno-economic data of the underlying production processes. It includes all processes involved in the conventional and low-carbon production of ammonia, bricks, clinker, container glass, corrugated board, float glass, graphic paper, HVC, methanol, newspaper, primary aluminum, primary copper, primary steel, quicklime, refractories, secondary aluminum, secondary steel, soda ash, or tissue. Second, after deriving the national energy requirements, we regionalize those for hydrogen based on allocation keys for existent industrial sites for the base year 2018, assuming that production at these sites is maintained. To obtain the allocation keys, we merge data from five different datasets for Germany.

The results of our study are addressed to scientists and decision makers to gain a better understanding of energy-intensive industrial processes and their respective hydrogen requirements. We also present the regionalization to gain an understanding of future hydrogen infrastructure requirements.

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Analysis of hydrogen sorption capacity of $LaNi_4Al_xSn_{1-x}$ system

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Keywords: Hydrogen storage, intermetallic compounds, xrd study, p-c-T

ABSTRACT

One of the most promising hydrogen storage technologies is the reversible chemical bonding method using metal hydrides. Metal hydrides, such as LaNi5 or TiFe, have the ability to absorb and desorb hydrogen in reversible processes, which allows the repeated use of these materials for storing and releasing hydrogen. They are also characterized by a higher bulk energy density compared to liquid hydrogen. The storage process in these materials occurs through the absorption of hydrogen at high temperature, which leads to changes in the crystal structure and allows hydrogen to be stored at relatively low pressure. However, despite favorable properties, such as the ability to sorb hydrogen, their wider use in industry is limited by high costs and limited resources of some metals. In practice, metal hydrides can only store up to approximately (3-5)% of their mass as hydrogen, which poses challenges for applications where mass and storage volume are critical [1].

$LaNi_5$ can be combined with various elements, partially replacing the A or B sublattice and forming stable ternary alloys. Thanks to such a substitution, the enthalpy of hydrogenation can be adjusted and long-term stability can be improved [1,2]. By substituting metals such as Mg, Ca, Sr, Ba for La or metals such as Al, Co, Fe, Cr, Ge, Si, Sn, Pd, Mn, B, Se for Ni, attempts were made to investigate the possibility of achieving thermodynamic destabilization of the three-component hydride, reducing hydrogen sorption pressure or improving long-term cycling capabilities [3,4]. In [2] it was observed that the volume expansion is correlated with the atomic radii of the elements substituted for Ni and is below 4% for a significant part of the M elements in the chemical compound $LaNi_{4.75}M_{0.25}$.

The addition of tin (Sn) to replace Ni in LaNi5, forming alloys such as $LaNi_{4-x}Sn_x$ ($0 \leq x \leq 0.5$), has proven beneficial for hydrogen storage; this results in a larger unit cell volume compared to pure LaNi, a significant reduction in plateau pressure, and improved hydrogen storage properties [5]. Replacing Ni with Al turned out to be equally beneficial [4].

Therefore, it was interesting to see how $LaNi_5$ would behave in which Ni is substituted by both Sn and Al. For this purpose, $LaNi_4Al_xSn_{1-x}$ alloys (x = 0.2, 0.4, 0.6, 0.8) were prepared and subjected to structural (initial alloys) and sorption (H_2) analyses. The alloys were obtained by arc fusion in a protective Ar atmosphere, using the MAM-1 (Buhler) furnace. The *p-c-T* sorption measurements were performed using the HTP1-S analyzer (Hiden Isochema). Figure 1 (left) shows the X-ray diffractograms of the obtained samples. None of the doped samples retains the hexagonal structure of the starting compound $LaNi_5$ alone. Doping Sn and Al causes the formation of two- or even three-phase systems, where one of which may be a hexagonal structure identical to the space group (*P*6/*mmm*) of the starting $LaNi_5$. Despite the rather observed discontinuity in the formed structural phases, it is surprising that such continuity occurs in *p-c-T* sorption studies. In general, it should be stated that all tested $LaNi_4Al_xSn_{1-x}$ compounds were saturated with hydrogen very quickly at very low pressures (even from fractions of a bar). The sample with the lowest Sn (0.2) content had the highest maximum hydrogen saturation: approx. 1.25(3) wt%, while the lowest was observed in the sample with the highest Sn (0.4) content:

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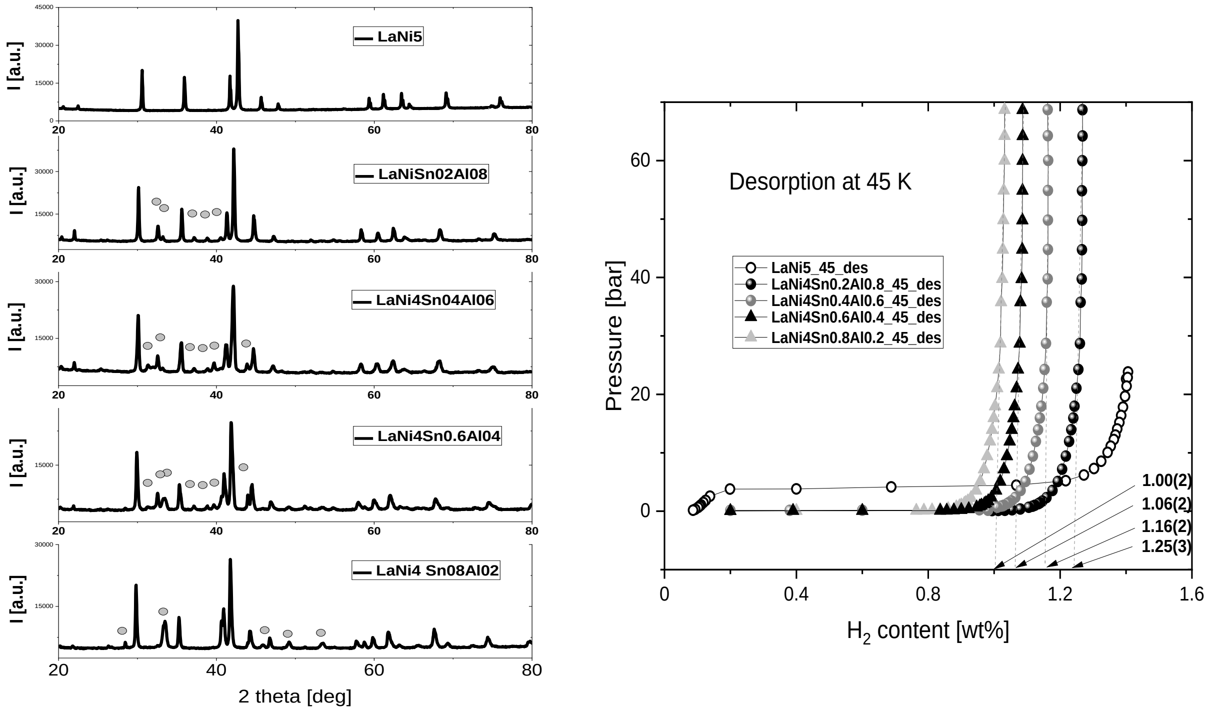

Figure 1. (left): XRD patterns of $LaNi_5$ and $LaNi_4Al_xSn_{1-x}$ alloys (x = 0.2, 0.4, 0.6, 0.8). Gray dots Gray circles indicate the strongest reflections coming from phases other than the hexagonal structure (P_6/mmm) typical for $LaNi_5$. (right):the p-c-T curves (desorption) for $LaNi_5$ and $LaNi_4Al_xSn_{1-x}$ alloys at 45 K.

approx. 1.00(2) wt%. The changes in hydrogen concentration are almost monotonic (Figure 1, right). This behavior indicates a significant share of elements creating hydrogen-saturated compounds. Structure, surprisingly, is of secondary importance here.
More results of structural and sorption tests (ab- and desorption) at various temperatures will be presented, as well as the results of SEM tests using an EDS head and the possible use of such compounds.

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Feasibility of radiopharmaceutical production in high temperature reactors

Mariusz Kopec[1]*, Grażyna Domańska[1], Jerzy Cetnar[1]

The aim of this work was to demonstrate the feasibility of using the HTR research reactor planned for deployment at IFJ Swierk, for the production of the radionuclide I125. This important radiopharmaceutical could be produced by irradiation of the natural xenon with a neutron flux in a channel located in the graphite reflector. The calculations has been performed with the MCB neutron transport and burnup code, for the initial model of the reactor core, called "TERESA", with a thermal power of 40 MW. The production of the radionuclide was not optimized, assuming that it would be done in a regular conditions, in a one vertical channel with a diameter of 12 cm and a height of 4.8 m, in a neutron flux of 1012 n/cm2s. The xenon irradiation time was fixed at 4 days with subsequent 8 days of cooling time. In these conditions the purity of produced isotope was quite good, since the concentration of the unwanted I126 isotope was less than 1%, and the total activity of I125 produced was as high as 300 GBq. The high efficiency of radionuclide production confirms the assumption that high-temperature reactors can be successfully used for the production of radioisotopes. Due to the high temperature and large space for exposure, they may be more efficient than the currently used methods.

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Hydropower in Poland – current status and development prospects

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Keywords: hydropower, electricity production, power plants

ABSTRACT

The Polish energy sector, like the energy sector of other European Union countries, is currently undergoing a transformation from conventional energy to renewable energy. This is not an easy or quick process. Especially in Poland, which for decades based its energy system on coal. As recently as 2022, electricity generated from coal accounted for approximately 70% of total electricity generated. The transition to renewable energy requires time and very large financial resources. More and more stringent EU standards, as well as the decisions of climate summits, impose on our country the obligation to change the energy mix to a more ecological one. To achieve this, solar, wind and water energy should be used to a greater extent than before. As for the latter, Poland produces little electricity from water. This results not only from the long-standing energy policy promoting fossil raw materials, but mainly from the lack of appropriate watercourses that could be used for this purpose. Despite having over 700 hydropower plants, the production of electricity from water amounted to only less than 2 TWh in 2022, which represented 0.6% of the total electricity production in Poland in that year. The low production of electricity from water, despite many power plants, is due to their low power. Poland has only five hydroelectric power plants with a capacity greater than 100 MW and two in the range of 50 - 100 MW. The remaining hydroelectric power plants are much smaller, so the global production of electricity from water is also small. As for the development prospects for hydropower in Poland, they are not very good. Nevertheless, investments in pumped storage power plants are planned. The development of these units has already been included in Poland's Energy Policy until 2040. This will allow, although only slightly, to increase the production of electricity from renewable sources, but above all it will increase the possibilities of energy storage. Such actions will enable more stable operation of the power system and improve its security.

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Selected environmental challenges in the face of the development of offshore wind energy in the Baltic Sea

Monika Rydygier[1]

ABSTRACT

Green energy is the key to reducing greenhouse gas emissions and fighting climate changes. Modern wind turbines have been recognized as one of most promising technologies within the ‘green energy’, they are being installed all over the world and are an important alternative to eliminating fossil fuels or other energy sources. Offshore wind energy is currently one of the fastest growing renewable energy technologies in the world, as location of turbines outside inhabited areas on land minimizes the nuisance of these devices to residents. Such dynamic development is reflected in the size and hi-tech solutions used in offshore wind turbines. Within a few years, the above-mentioned turbines will diversify the landscape of Polish Sea area. The Polish Energy Policy until 2040 indicates that the installed capacity in offshore wind energy will reach 5.9 GW in 2030, and up to 11 GW in 2040. The planned large-scale exploration of the Baltic Sea related to the construction and operation of offshore wind farms may increases the risk of turbine failure and, consequently, oil pollution entering the Baltic Sea. Therefore, solutions are necessary to limit environmental damage to a minimum. The article discusses how significant the risk of such pollution is and what countermeasures are currently the most effective.

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Assessment of the economic and ecological effect of installing photovoltaic panels on building roofs on the example of AGH

Grzegorz Jodłowski[1],*, **Sylwia Wójcik**[2]

Keywords: solar energy, photovoltaic panels, ecological effect, economic effect

ABSTRACT

Solar energy is a broad concept used in many cases. In the analysis below, we focused on converting the sun's energy into electricity through various types of photovoltaic panels. In this case, the important aspects are relief of the terrain, cloud cover in terms of the type and amount of clouds, seasons of the year and the location of photovoltaic panels as well as the location on the map. These factors are important because, depending on them, we receive the appropriate amount of solar energy, which we can transform into electricity that we use every day. A good example of using solar energy in everyday use is the installation of photovoltaic panels on the roofs of the AGH University of Science and Technology in Krakow. According to general data for Poland, the average sunshine in 2020 for the northern region was 35%, and in the remaining area from 46% to 48%. The average amount of sunshine is 1,650 hours per year. Four types of photovoltaic panels were taken into account for the analyses: monocrystalline cells, polycrystalline cells, amorphous cells and perovskites. The average annual solar energy (84.75 kWh/m^2) was used for the research, and the potential available energy for each cell was calculated, taking into account individual buildings and their sum. Costs for individual photovoltaic panels were estimated. Then, the average costs of installing individual photovoltaic cells were compared. The last stage was to select the most profitable photovoltaic cell in terms of economics and ecology. The economic effect is the financial savings that will occur when a renewable energy source is used. The ecological effect is the use of a renewable energy source instead of a conventional one, increasing the share of renewable energy sources in the energy mix and reducing carbon dioxide emissions, which may also result in lower costs. After comparing the results, the most cost-effective solution turned out to be installing perovskites on the roofs of university buildings. At the current rate of PLN 1.12 per 1 kWh, the saved costs would amount to PLN 618,351. Calculated time of recovery in methodology SPBT is about 3 years.

The estimated coverage of the energy use in the AGH by the installation of solar PV is at the level of 3% in the best scenario.

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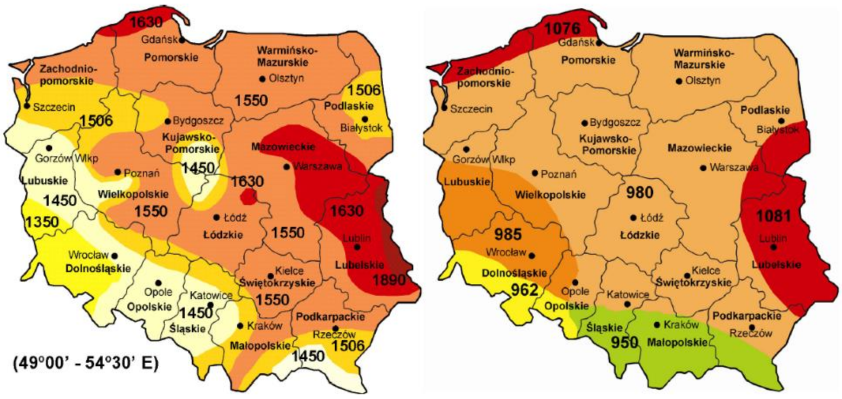

Figure 1. Average annual total sunshine [hour/year] Radiation density [kWh/m²year] [1]

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Introducing circular economy principles in a biotechnology laboratory

Grzegorz S. Jodłowski[1,*], Edyta Strzelec[1], Patryk Zdziobek[1], Marta Wójcik[1]

Keywords: biotechnology, circular economy, biocomponents

ABSTRACT

Implementing principles of the circular economy in a biotechnology laboratory can significantly reduce waste, improve resource efficiency, and enhance sustainability.
Circular economy is based on three fundamental principles:

- eliminate waste and pollution,
- circulate products and materials,
- regenerate the environment.

The above means in the laboratory optimized use of reagents, sharing resources like appliances or substrates/products, waste minimization, sourcing from local waste material to omit conflict with other production areas, energy-efficient equipment and processes and use of a closed-loop system as well as use of biotechnology processes to treat waste to reduce of environmental pollution.

The described practices are implemented in the biotechnology laboratory concerned with biofuels or biocomponent production. A process or set of processes designed for energy harvesting by biotechnology way with minimal environmental impact and possibly a closed cycle could be called the BIOPOWER. Previously independent experiments were combined to minimize byproducts.

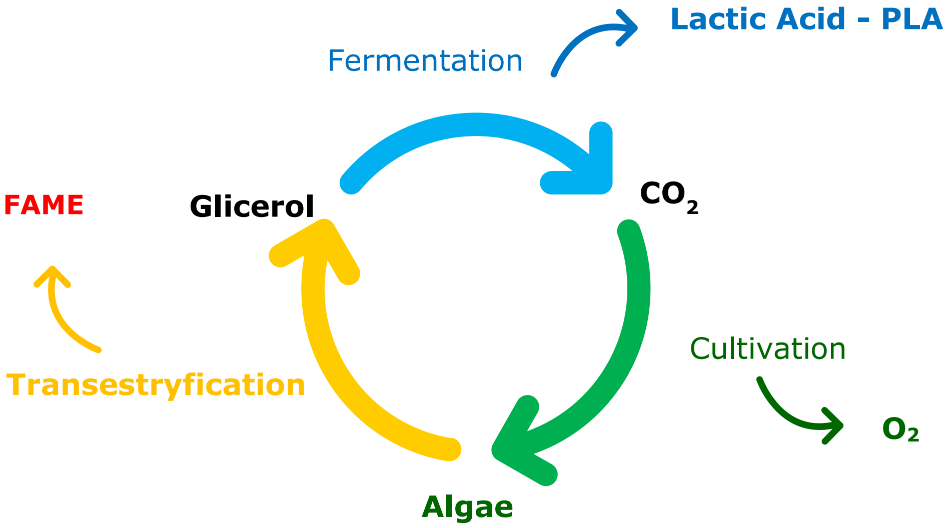

Figure 1. Scheme of the process circle in the bio-lab

Figure 1 shows the scheme introduced in our laboratory. Some experiments were connected directly, and others were in the idea phase of a new closed process. Experiments were carried out with the processing of glycerol as a by-product of transesterification into FAME towards lactic acid [1], which could then be processed into its polymer - PLA. Combined experiments focused on the production of antioxidants for the preservation of

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the biocomponent of diesel fuel, also using lactic fermentation [2]. The byproduct of lactic heterofermentation was carbon dioxide. Another experiment was conducted to check carbon dioxide absorption during microalgae cultivation [3]. Biomass was produced in photobioreactors, for which the concept of using a biodiesel component [4,5] for production emerged, which would eliminate the cyclical use of substrates-products in the laboratory. Thus, a kind of synergy emerged in which individual experiments supported each other and at the same time, the amount of waste produced or the need for raw materials was minimized.

The above concept does not exhaust all possibilities of using the bioreaction cycle and the products occurring in it. Some of them, after selecting optimal conditions, can be used to clean the local environment and produce oxygen.

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Pharmaceuticals and its transformation products in the aquatic environment – origin, fate, occurrence and toxicity

Katarzyna Nosek[1],*

Keywords: emerging contaminants, drug metabolites, transformation products, toxicity, aquatic environment

ABSTRACT

Pharmaceuticals have become increasingly recognized as emerging contaminants (ECs) in the water environment. These contaminants enter the water, primarily through wastewater discharge. The most well-known classes of ECs include antibiotics, hormones, and nonsteroidal anti-inflammatory drugs (NSAIDs). Their bioactive nature raises concern about the potential impact on non-target organisms. Several compounds, such as certain estrogens, antibiotics, diclofenac, venlafaxine, and desmethylvenlafaxine, have been included in Watch Lists under the Water Framework Directive to be scrutinized for the purpose of determining the risk they pose. However, none have yet become priority substances for routine monitoring. Although knowledge of the occurrence and toxicity of ECs is growing, it is still too limited for reliable risk assessment. This is largely due to the significant analytical difficulties in detecting trace contaminants in complex environmental matrices (e.g. wastewater) and the frequent lack of analytical standards. It is worth noting that most studies assess risk based on single parent compounds, often ignoring possible synergistic interactions with other co-contaminants as well as drug transformation products.

This work provides a broader perspective on the presence of pharmaceuticals in the environment, using several NSAIDs as examples. First, according to pharmacokinetic data, pharmaceuticals are excreted primarily in the form of metabolites, making metabolites more abundant in wastewater streams than the original drug. Using diclofenac as an example, the main metabolites of the drug include hydroxy and methoxy derivatives (e.g. 4′-hydroxy-diclofenac, 5-hydroxy-diclofenac, 4′, 5-dihydroxy-diclofenac etc.) and conjugates of the parent drug and phase I metabolites. Metabolites are more hydrophilic than parent drugs, which implies weaker sorption potential and higher mobility in water environments. Second, pharmaceuticals may undergo uncontrolled conversion reactions in the environment, generating multiple transformation products. For example, biological wastewater treatment produces transformation products of diclofenac similar to human metabolites. In natural waters, photolabile drugs can be degraded via photolysis, creating additional transformation products. For instance, diclofenac photodegradation yields multiple carbazole compounds and diphenylamine derivatives. Third, during treatment processes some metabolites of diclofenac may revert to the original form of drug, establishing a background reservoir for the drug. This explains why diclofenac is often observed in higher concentrations in effluent compared to influent wastewater. Fourth, some transformation products retain the core structure of the drug and may pose similar or even greater risks to the environment than the parent compound. For instance, hydroxylated metabolites and nitro derivatives of diclofenac can exhibit similar or higher toxicity to certain bacteria. Photodegradation by-products of diclofenac, such as 2-[(2-chlorophenyl)amino]benzaldehyde, may also exhibit greater toxicity to bacteria, algae, and fish. Moreover, mixtures of pharmaceuticals, their metabolites, and other co-existing compounds pose elevated and synergistic environmental risks compared to individual compounds. In conclusion, pharmaceuticals are present in the environment partly in the

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form of metabolites and other transformation products, which can still affect water environments. Neglecting these background levels may result in an underestimation of the risk associated with pharmaceuticals. Therefore, it is crucial to study drug transformation products along with the parent compounds for a comprehensive risk assessment.

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Characterization of gamma radionuclides in tobacco cultivation and processing

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Keywords: tobacco products, gamma radionuclides, tobacco cultivation

ABSTRACT

Tobacco is a plant grown mainly for tobacco production. It has many types and varieties that have individual needs for soil and fertilizers. The most popular types of tobacco include Virginia tobacco and Burley tobacco, both of which have their own varieties. The type of soil is an important factor in tobacco cultivation. Lighter soils are recommended for Virginia tobacco and medium-heavy soils for Burley tobacco. For tobacco, fertilizers such as magnesium sulphate, phosphate, nitrabor and potassium salt are used. A mature tobacco plant is harvested and dried in a multistage process, receiving appropriate products and by-products at each stage. Each stage may contain radionuclides that are an integral part of the environment. They may owe their origin to natural phenomena as well as to their introduction into the environment by humans or constantly developing infrastructure. Due to its morphological structure, tobacco has a greater absorption of radionuclides from its surroundings. The relevant products include dried tobacco, the composition of which, depending on the class, includes different parts of tobacco. Another product is tobacco vein, and tobacco dust is classified as a by-product not used in tobacco products. The aim of our research was to determine the content of gamma radionuclides in Virginia and Burley tobacco, tobacco veins and dust, the soil where tobacco is grown and the fertilizers used. A gamma spectrometer (BE3830 type model) was used to identify gamma radionuclides such as: ^{137}Cs, ^{40}K, ^{228}Th, ^{228}Ra, ^{226}Ra, ^{210}Pb, ^{238}U, ^{235}U and ^{241}Am. The concentration of radioisotopes in the analyzed samples varied. For example, the content of ^{238}U in soils ranged from 19.63 ± 3.82 to 35.30 ± 2.62 Bq·kg^{-1}. In most tobacco samples, the radioactivity of the isotope was below the detection limit except for ^{40}K. In fertilizers, the highest radioactivity was found for phosphates. The level of ^{210}Pb was 435 ± 16 Bq·kg^{-1}. The results of the tobacco vein are similar to those of dried tobacco, while the tobacco dust was also characterized by a high content of ^{210}Pb and the presence of ^{228}Ra (9.08 ± 2.42 Bq·kg^{-1}) and ^{226}Ra (12.40 ± 1.76 Bq·kg^{-1}). The occurrence of gamma radionuclides depends on many factors, including: soil type, tobacco variety, fertilizers used, agricultural practice and method of processing the material at individual stages.

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Applications of silicon-based nanoparticles in the energy sector and biotechnology

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Keywords: Si-based nanomaterials, energy harvesting, biotechnological tools, environmental safety

ABSTRACT

Silicon-based nanomaterials have many attractive chemical, mechanical, and physical properties. The latest research on the applications of silicon carbide SiC, silicon nitride Si_3N_4 or silicon oxynitride Si_2N_2O, as well as commonly known and used silica SiO_2 nanoparticles, is summarized. Such research indicates that in addition to the already known applications, new possibilities of their use are also emerging in various areas, such as energy and biotechnology. For example, the semiconducting properties of silicon carbide determine its applicability in the electronic field, especially with devices that operate at high temperatures and high power. Its resistance to high temperatures and radiation makes it useful in nuclear power and solar energy harvesting or as a catalyst support in some high-temperature catalytic reactions. Due to high mechanical strength and resistance to oxidation and thermal shocks, silicon nitride is used as a construction material for devices operating under harsh conditions of strong magnetic and electric fields. It is also a promising material for use in the production of photovoltaic panels, serving as antireflective coatings that improve the ability of the panels to absorb solar radiation. The attractive surface properties of mesoporous silica are used in catalytic reactions as a catalyst support. Because silica and SiC can be easily functionalized, they are often used as analytical tools, e.g. biosensors for environmental protection, food industry, and medical diagnostics. Biosensors have been used to identify pathogens and drugs in biological materials, groundwater, and food products. Si-based nanomaterials can also be used in bioreactors to remove contaminants. They have also found numerous biomedical applications, including drug delivery, bioimaging, and regenerative medicine. The mesoporous structure of these materials facilitates the uniform dispersion of drugs in the matrix, allowing controlled drug release. Silica nanoparticles have been used in various cancer imaging techniques, such as light imaging with fluorescence-emitting dyes, imaging with radioisotopes (^{89}Zr, ^{99}Tc), and magnetic resonance imaging. The fastest-growing photodynamic therapies in cancer treatment, which combine diagnostic imaging with drug delivery, use nanomaterials. Mesoporous SiO_2 nanoparticles with the addition of photosensitizers are often used for this purpose. In targeted therapy, a tumor loaded with such a nanomaterial will be irradiated by near-infrared radiation, releasing free radicals that lead to the local death of cancer cells. Because of favorable mechanical properties, biocompatibility, and antibacterial properties, silicon nitride is used in tissue engineering, where, among others, it is used to produce nanoscaffolds for bone reconstruction, in particular craniofacial bone, and to fill dental defects.

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Cross-sectoral modelling approach to design energy transition and decarbonisation pathways for district heating systems

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Keywords: energy modelling, district heating, capacity expansion, decarbonization, geospatial data

ABSTRACT

Currently, most district heat in Poland is still produced using fossil fuels. District heating (DH) systems are, therefore, an important part of the energy transition of the Polish economy, also in the context of utilising the overproduction of electricity from intermittent RES sources. Moreover, district heating can also play a significant role in decarbonising other sectors, e.g., residential, by replacing individual fossil fuel boilers as a heat source.

District heating networks operating in many cities, unlike the electric grid, are separate entities and trading heat between systems is impossible. They vary considerably in terms of heat demand, capacity, and types of generation units, as well as local conditions, such as fuel availability. Commonly used in policy development, long-term optimisation models often treat district heating systems as a single system and, therefore, cannot properly represent these individual characteristics. On the other hand, the detailed models of individual systems used by their operators to plan future development make many exogenous assumptions. In particular, assumptions about the price of electricity, which is both the main driver of Power2Heat technologies and a product if DH system comprises a CHP plant.

There is therefore a case for a modelling framework that reflects the characteristics of individual district heating systems, while treating them as a part of the overall energy system. This will allow a better representation of the dynamics between district heating systems and the rest of the energy system, as well as a better understanding of the role of district heating systems in the energy transition.

An optimisation model, named TIMES-HEAT-PL, was created using the TIMES model generator for capacity expansion planning. In the model, district heating systems are represented as regions representing aggregates based on similar characteristics. The characteristic include: 1) a set of existing heating and/or CHP plants; 2) a heat demand curve; 3) fuel prices and availability of energy sources; 4) a set of new technologies in which the model may invest in the future, including heat storage. As district heating systems are represented as separate regions, many of the characteristics listed above are based on the geographical location of the system. For example, the availability of geothermal technology, fuel delivery costs, and solar irradiance profile. The national energy system is modelled as a separate 'global' region with which all district heating regions can trade commodities such as electricity. This global region is at the same time a way of linking the TIMES-HEAT-PL model with the external national energy system model (TIMES-PL). Both models are coupled and exchange information on installed generation capacity to better reflect the impact of changes in the district heating sector on demand sectors.

The main result of the TIMES-HEAT-PL model is a cost-optimal mix of new heat generation capacity and heat generation profile for each aggregate of district heating systems. This includes the new heat storage and Power2Heat installations and their operating profile. On this basis, the price of heat generation can be calculated for each

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*corresponding author: makracz@agh.edu.pl aggregate of systems. As the price of heat is the main factor determining the competitiveness of district heating systems with other heat sources, it can be used to assess the level of support district heating systems will require on the path to decarbonisation. The exchange of data with the national energy system model can allow a better representation of the development of district heating systems in the context of the energy transition of the entire economy.

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Laboratory studies of salt rocks to assess the feasibility of large-scale hydrogen storage in salt caverns

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Keywords: hydrogen storage, salt caverns, salt permeability, geochemistry

ABSTRACT

One of the essential tasks of the energy transition will be developing and implementing an effective energy storage method that allows for an increased share of renewable energy sources (RES) in the energy mix while maintaining the stability and reliability of the power system.

Green hydrogen (produced through electrolysis powered by RES) is expected to become the energy carrier. The most promising method for hydrogen storage is underground cavern storage in salt deposits. The cavern storage technology has proven successful for hydrocarbon storage and can now be adapted for hydrogen storage. Several caverns store hydrogen worldwide (in the UK, France, and the USA), and many countries have ongoing demonstration projects.

The storage of hydrogen in caverns will be similar to natural gas storage. However, it requires laboratory research on salt rocks where the caverns will be located. The rock studies must consider local geological conditions, including the deposit form (bedded, domal) and various lithotypes of salt rocks.

As part of the implementation of a large-scale project for hydrogen storage in salt caverns, experiments were designed and conducted to determine petrophysical parameters (permeability, porosity) for the main lithotypes of evaporitic rocks isolated in the Mechelinki bedded salt deposit (UGS Kosakowo) and the Mogilno domal salt deposit (UGS Mogilno) [1]. The analysis also included studying the interaction in the rock-brine-hydrogen system (seasoning rock samples in autoclaves with brine and hydrogen). Petrophysical studies were conducted before and after the interaction analysis to determine the impact of hydrogen on petrophysical parameter changes.

Permeability (a fundamental parameter for sealing rocks) for co-occurring rocks and pure salts ranges from 1.04×10^{-17} to 3.19×10^{-20} m² for helium and from 1.37×10^{-17} to 0 m² (impermeable samples) for hydrogen. The findings align with the ranges presented in the literature for hydrogen storage [2-6].

The analysis of changes in salt rocks after interaction with hydrogen revealed:

- Dissolution of anhydrite, halite, and carbonates
- Crystallization of halite and gypsum

These observed processes affect petrophysical parameters (pore size distribution and rock permeability). Due to the opposing nature of these processes, these changes will not adversely affect the integrity of potential hydrogen storage facilities.

It was also observed that hydrogen-brine-rock interaction can introduce hydrocarbon traces (C_1, C_2, and C_8) due to the dissolution of oil inclusions in halite. Additionally, carbonate dissolution can result in the presence of carbon dioxide and carbon monoxide, potentially impacting gas quality.

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Table 1. Permeability before and after the hydrogen-brine-rock interaction

	Sample #						
	1-1	**2-1**	**3-1**	**4-4**	**5-1**	**6-1**	**7-1**
C_1	0.00004	0.00004	0.00016	0.00004	0.00004	0.00005	0.00005
C_2	0.00000	0.00000	0.00004	0.00001	0.00000	0.00000	0.00000
C_3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
i-C_4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
n-C_4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
neo-C_5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
i-C_5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
n-C_5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
ΣC_6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
ΣC_7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
ΣC_8	0.00035	0.00000	0.00000	0.00000	0.00000	0.00026	0.00000
ΣC_9	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
ΣC_{10}	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CO_2	0.00527	0.02042	0.00737	0.01624	0.01761	0.03011	0.01617
N_2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CO	0.00000	0.00005	0.00026	0.00010	0.00010	0.00010	0.00022
He	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
H_2	99.99434	99.97949	99.99217	99.98361	99.98225	99.96948	99.98356
H_2S	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mer. methyl	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mer. ethyl.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Dimethyl Sulfide	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mer. i-prop.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mer. n-prop.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mer. i-buthyl.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Mer. n-buthyl.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

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Analysis of Non-Market Redispatching of Power Generation from Variable Renewable Energy Sources

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Keywords: power system, planning, renewables, curtailment

ABSTRACT

Weather-dependent or variable renewable energy sources (VRES) constitute an increasing share of energy production in the Polish power system. In the last three years, power capacity increments have reached about 1 GW per year for onshore wind and three times that for photovoltaics. In May 2024, the total installed electrical capacity in VRES amounted to approximately 27.5 GW, with almost 18 GW installed in photovoltaic installations and about 9.5 GW in onshore wind turbines. Operational planning of the National Power System (KSE) with a high penetration of RES poses a significant challenge for the Transmission System Operator (TSO). The primary tool for balancing the power system is market mechanism, i.e., the purchase and sale of electricity in the wholesale market conducted by market participants. The wholesale market, especially its spot segments, are currently fully integrated with the European market. In operational planning, the operator prepares work plans based on, among other things, energy sales contracts reported by wholesale market participants. Electricity markets in Europe are zonal markets, meaning that every bidding zone is represented as a single node, which most often coincides with a country (e.g., Poland is one bidding zone). Although the algorithm for market coupling considers the power flow limits between the nodes, it is assumed that within a node there are no transmission limits. This assumption may lead to technically infeasible generation schedules set upon from market clearing. Moreover, such generation schedules do not take into account the detailed technical characteristics of generation units, such as minimum power output, cold/warm/hot starting time or ramping rates of dispatchable units. This is particularly important for the Polish power system, in which coal-fired units still prevail. In the context of rising VRES power generation, especially from PV, another challenge is the "duck curve" phenomenon, which requires a massive evening power ramp-up when solar power generation decreases and, consequently, the residual load on the grid rises sharply. To balance the evening load, an adequate number of dispatchable units must be operating at least at their minimum level during the midday dip in residual load. These units will be able to ramp up their power output quickly from the minimum to maximum level later in the day, but only if they are online. This is why the TSO must maintain such units during the midday dip, even if there is VRES oversupply at that time. Consequently, in such situations, the TSO requests a decrease in renewable generation, offering compensation to the renewable generator for curtailing its generation. This is known as Non-Market VRES Redispatching. The analysis presented in the paper indicates that VRES curtailment is becoming more frequent. In 2023, curtailment occurred for 19 hours, typically on Sundays when power demand was low (around 14 GW). By May 19, 2024, curtailment had already occurred for 162 hours, even during times when power demand was close to 21 GW. From the perspective of power system flexibility, it is noteworthy that the aggregate minimum capacity of dispatchable units during the midday dip in system load was about 4.6 GW, accounting for approximately 28% of overall power demand. In such situations, electricity prices on the balancing market, which form the basis for compensating VRES generators for lost production, were relatively low (PLN/MWh): min.: -125, max.: 364, Q2 = 10.

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Potential and considerations for the use of biomethane in the decarbonisation process

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Keywords: biomethane, alternative fuels, decarbonisation, biomethane upgrading, mixing system

ABSTRACT

The economic development that has been taking place over the past decades, combined with the growth of the world's population, have contributed to a sharp increase in energy consumption. Currently, fossil fuels are the dominant energy source in the energy market. This state of affairs has a very negative impact on the environment, contributing to the continued increase in greenhouse gas emissions and air pollution [1]. The main industries responsible for the largest share of greenhouse gas emissions are steel (6.2%), cement (3%), petrochemicals (3.6%), chemicals (2.2%) or non-ferrous metal production (about 1%). The mentioned production processes are characterized by a high rate of energy consumption, directly related to the need for high process temperatures, well above 1270 K in many cases. This situation makes it necessary to look for new solutions to decarbonize production processes.

The dominant trend is to replace both, electricity and heat produced from fossil fuels, with energy from renewable sources. This is particularly advantageous for electricity generation, such as with photovoltaic panels or wind power. Unfortunately, in the case of thermal energy, especially in high-temperature processes, solar or wind energy is not directly feasible.

One possible solution is to replace fossil fuels with alternative fuels derived from the processing of renewable energy resources. Among the new fuels are biogas and especially the resulting biomethane (green methane) and hydrogen, ammonia or synthetic gas.

Biomethane-based thermal energy production is one of the ways to decarbonize energy processes using alternative energy sources. In fact, carbon dioxide is produced as a result of its combustion, but it is absorbed during the growth of plants that are substrates for its production. This makes it possible to achieve zero greenhouse gas emissions [2, 3].

Importantly, biomethane as a gaseous fuel has physicochemical properties comparable or even the same as natural gas, which is currently commonly used in the previously mentioned high-temperature processes. This means that it will be possible to use currently used devices without the need to modify them or even replace them, which may occur if natural gas is replaced by a fuel with significantly different properties (e.g. hydrogen, ammonia).

Currently, there are less than 400 biogas plants in Poland, which is a value very far from our national potential. For comparison, Germany has over 11,000 biogas plants, Italy over 1,700, and France almost 900. Even the Czech Republic, much smaller than Poland, has nearly 600 biogas plants [4]. It is estimated that the potential for biogas production in Poland is 13-15 billion m^3/year. Such biogas production may translate into the production of 7-8 billion m^3/year of biomethane [5]. This is a significant value, considering that in 2023, natural gas consumption in Poland amounted to approximately 17 billion m^3 [6].

It should be noted that the launch of the first biomethane plant in Poland is planned for this year, so currently the number of operating refining installations in Poland is zero.

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For comparison, there are over 300 of them in France, over 200 in Germany, and in countries much smaller than Poland, such as Sweden, the Netherlands and Denmark, there are over 70, 60 and over 50 biomethane plants [4].

As it turns out, one of the main factors influencing the slow development of biogas upgrading installations, apart from the very slow development of the biogas market, are legislative aspects. On the one hand, there are no clear guidelines on what requirements biogas upgrading installations must meet, and on the other hand, there are various requirements set by transmission network operators. One of the key criteria for introducing biomethane into the transmission network is obtaining the appropriate calorific value. Namely, the HHV of the fuel introduced into the network cannot differ by more than 3 to 4% in relation to the fuel transmitted through this network. Bearing in mind that the calorific value of natural gas distributed in Poland varies depending on the region from 38 to almost 44 MJ/Nm^3, it turns out that in parts of Poland it is not possible to introduce biomethane into the transmission network. This is due to the fact that the HHV of biomethane is 38-39 MJ/Nm^3. To be able to introduce biomethane into the transmission network, it is necessary to enrich it, e.g. by adding propane, which is possible thanks to the biomethane enrichment installation shown in Figure 1.

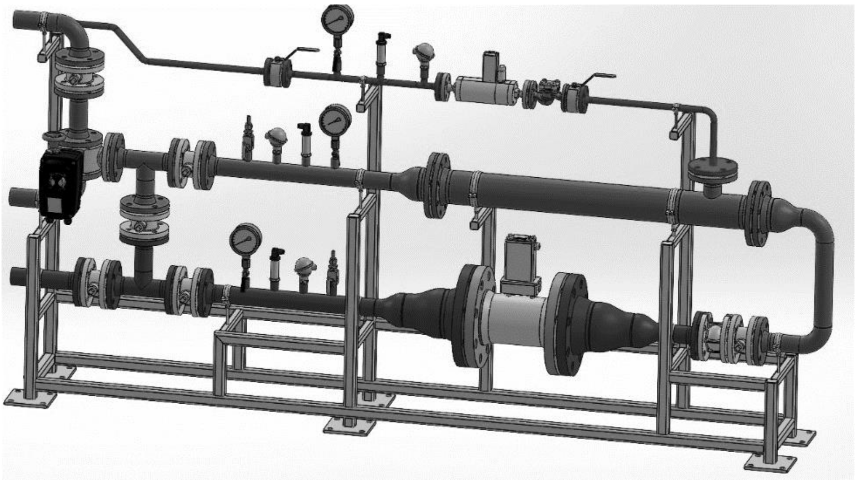

Figure 1. Visualisation of the biomathane upgrading system

The installation presented in Figure 1 must simultaneously control the composition of refined biomethane and biomethane enriched by adding propane, so as to meet the requirements regarding the calorific value of the gas to be introduced into the transmission network. Additionally, it should be emphasized that the lack of a clear interpretation of existing regulations means that potential producers of biomethane do not have information whether enrichment can be carried out by adding propane from fossil fuels or whether it must be biopropane from renewable sources.

The lack of clear regulations, as well as public opposition to the construction of facilities such as biogas plants, mean that the process of decarbonization of industry in Poland using biomethane, but also biogas, is much slower than possible and does not fully utilize the available potential.

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Analysis of the improvement of air quality in Poland in the 21st century in the context of a change in the method of heating in individual energetics

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Keywords: air quality, low emission, individual heating sector

ABSTRACT

The current policy in the individual heating sector in Poland, as well as economic, social and technical factors affect the constant changes in trends in the use of energy carriers and heating devices by the end user. Individual energy in Poland is still based on fossil fuels, which power heating devices in single-family and multi-family buildings. Among the most harmful fossil fuels due to the high level of emissions, we include hard coal, whose chemical composition and surface pollution affect the final level of concentrations in the exhaust gases. For several years, there has been an intense increase in the level of subsidies for the replacement of environmentally inefficient heat sources, the effect of which is expected to improve air quality and reduce the combustion of solid fossil fuels, as well as products that are not dedicated to combustion in heating devices. In addition to the aspects related to the use of various types of fuels for combustion, also an important aspect affecting the economy and ecology of the devices are operational aspects and user habits, which have a direct impact on air quality in Poland.

As part of the research, an analysis of concentrations of harmful substances was carried out, such as: sulphur dioxide SO_2, carbon monoxide CO, particulate matter PM_{10}, $PM_{2.5}$, as well as nitrogen oxides NO_x, as the main components of exhaust gases from combustion in individual thermal power generation. The analysis was prepared in relation to the 21st century, i.e. the years 2000 – 2023. The measurement data was obtained thanks to the functioning of the State Environmental Monitoring established under the Act on Environmental Protection Inspection [1]. The structure of the SEM consists of a network of measuring stations located throughout the country, with a specification of places associated with high intensity of emitted harmful substances. The stations record data at 1-hour or 24-hour intervals with the possibility of transmitting data electronically to the national JPOAT2.0 database. The collected data are made available by the Chief Inspectorate of Environmental Protection in the measurement data bank [2]. Currently, there are about 200 current and active stations in Poland, which, depending on the type of measuring device, can record the concentrations of selected air components. A summary of methods for measuring harmful substances is presented in the table below.

Table 1. The summary of measurement methods for individual harmful substances

No.	Substance	Measurement methodology	Compliance with the standard
1.	Nitrogen oxides - NO_x	Chemiluminescence	PN-EN 14211:2013-02
2.	Sulfur Dioxide - SO_2	Ultraviolet fluorescence	PN-EN 14212:2013-02
3.	Particulate Matter – PM_{10} Particulate Matter - $PM_{2.5}$	Gravimetry (Reference)	PN-EN 12341:2014-07
4.	Carbon monoxide - CO	Non-dispersive infrared spectroscopy	PN-EN 14626:2013-02

On the basis of the data obtained, statements of annual concentrations were prepared,

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as well as indications for the heating season, as well as the period outside the heating season. According to the Polish state of heating, taking into account temperature data, it was assumed that the heating season corresponds to the period from October 1 to March 31 of the following calendar year, while the remaining period during the year is the period outside the heating season.

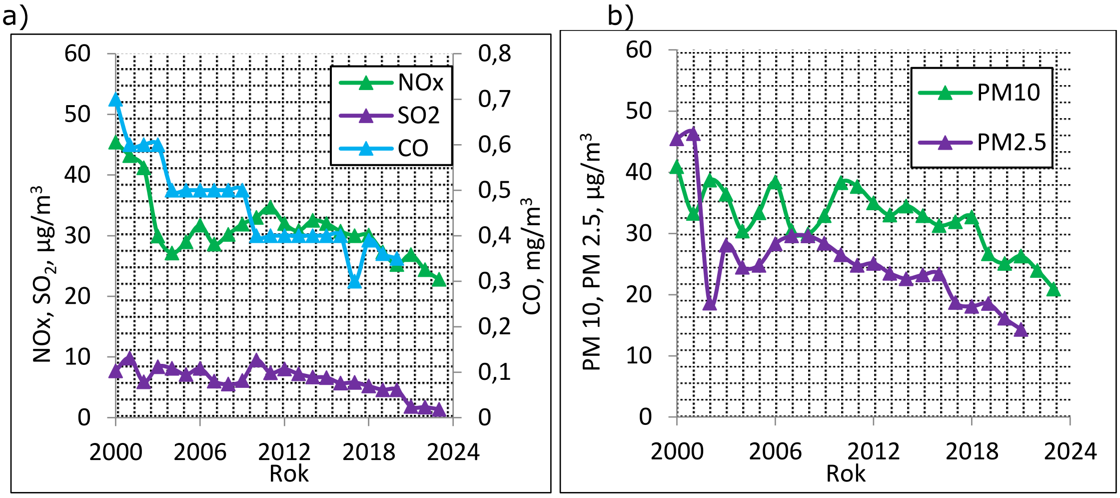

Figure 1. Course of anual concentration levels of a) NO_x, SO_2, CO and b) PM_{10}, $PM_{2.5}$

The main conclusion of the analysis is that the trend in the concentration of harmful substances such as SO_2, CO, PM_{10}, $PM_{2.5}$, NOx is decreasing, but there are still noticeable exceedances of the permissible alert levels. The evidence confirming the fact that the heating sector as the main element affects the air quality in Poland are the differences in the levels of concentrations of flue gas components between the heating season and outside of this period. The summary of seasonal emission courses showed decreases in the concentrations of the tested pollutants in non-heating periods. For NO_x it was a decrease by 33.2%, for SO_2 by 55.6%, for CO by 40.7%, for PM_{10} by 41.8% and for $PM_{2.5}$ by 53.1%. In order to achieve measurable effects and reduce emissions from the heating sector, actions should be aimed at optimizing the use of heat sources, adjusting standards for testing heating devices, especially in the case of real operating conditions of heating boilers, as well as strengthening the measurement infrastructure in order to eliminate concentrations of permissible concentrations of substances threatening the health and life of the society. The next step should be to prepare a decision-making model for the interchangeability of solid fuels, taking into account economic, social and technical factors in terms of optimal decommissioning of environmentally inefficient equipment.

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[4] PN-EN 14212:2013-02, Atmospheric air. A standard method for measuring sulfur dioxide concentration using ultraviolet fluorescence.
[5] PN-EN 12341:2014-07, Atmospheric air. A standard gravimetric measurement method for determining mass concentrations of PM10 or PM2.5 fractions of particulate matter.
[6] PN-EN 14626:2013-02, Atmospheric air. Standard Method for Measuring Carbon Monoxide Concentration by Non-Dispersive Infrared Spectroscopy

Spectroscopic structural properties of proton ionic conductors based on Uranyl Hydroxy-Phosphate and Hydroxy-Arsenate

obtained in a mechanochemical synthesis

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Magdalena Dudek[4], Maciej Siekierski[2]

Keywords: PEMFC, proton conductors, uranyl phosphates, uranyl arsenates, glass-crystalline composite, mechanosynthesis, FTIR, FT-Raman, Terahertz spectroscopy,

ABSTRACT

A need for small-sized (10–100W) fuel cells operating in the temperature regimes allowing lower purity hydrogen usage is a purpose to develop new types of proton-conducting membrane materials for PEMFCs.

The idea of using mechanosithesised hydrogen uranyl phosphates (HUP) and hydrogen uranyl arsenates (HUAs) in the form of glass-crystalline composites as proton-conducting membrane materials was investigated.

Electrical parameters of the membrane depend on molecular structure and the phase transitions, as well as, hydration and dehydration processes. Just as important is the molecular hydrogen effect on the membrane materials developed. So these phenomena are the priorities to spot and recognise since they may influence the electrochemical behaviour of the systems.

According to the mixed crystalline-amorphous nature of the investigated materials spectroscopic techniques like FT-IR, and FT-Raman, are adequate methods to track the structural changes.

Terahertz spectroscopy was additionally, used to observe directly the mobility of the water molecules [1], as well as, the hydration level of the materials [2] investigated.

Previous research on the materials demonstrated that glassy conductors comprising of interpenetrating inorganic networks of poly-silicate and poly-phosphoric acids, as well as, their composites with various crystalline proton transporters develop highly promising functional and operational properties including electrochemical stability fairly exceeding both the commercialised and laboratory-developed their polymeric counterparts [3,4].

Therefore, a deepened investigation of the composite of phosphate silicate protonically conductive glass with uranospinite type crystalline materials such as hydrogen uranyl phosphates (HUP) and hydrogen uranyl arsenates (HUAs) [5,6] exhibiting in their pristine dry state protonic conductivity was performed by means molecular spectroscopy methods.

The substrates for high-energy mechanochemical synthesis were obtained by, sol-gel (phopspho-silicate glasses) and solvothermal synthetic routes (HUP, HUAs crystalline materials) The palletization of powdered final product allowed to perform further electrochemical characterisation. The molecular spectroscopy results also allowed us to gain insights into conductivity mechanisms as well as its in situ version FTIR-ATR temperature experiments were informative in this area.

Using terahertz spectroscopy, an interesting correlation with network stretching oscillations was recognised for a band located around 4-5 THz, and probably the translational movements of the molecules of the hydrogen bond could be identified in this range.

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So heating colling stability as well as chemical stability against hydrogen was verified for selected compositions.

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Application of principal component analysis to the interpretation of gamma radionuclide content in technogenic soil profiles

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Keywords: TENORM, PCA, technogenic soil, gamma radionuclides

ABSTRACT

This paper presents an attempt to use principal component analysis (PCA) to interpret the activity of gamma radioisotopes in the profiles of technogenic soils formed at the ash disposal sites of thermal power plants. Six soil profiles from four different power plants were analyzed. Three profiles from the power station burning bituminous coal and three from the power station burning lignite. PCA was proposed because in radioisotope studies there is a problem with interpreting the results for soil samples taken by soil scientists. Methods of collecting soil samples by soil scientists involve making a vertical excavation of the soil profile. It is not possible to determine the area of the collected soil sample and relate it to the mass of this soil. Lack of knowledge of the area of soil was collected, its mass and density do not allow conversion from the native unit Bq·kg^{-1} to Bq·m^{-2} and for a simple summation of the gamma activity of isotopes from individual horizons of the soil profile. The following gamma radioisotopes were determined: ^{40}K, ^{228}Th, ^{226}Ra, ^{210}Pb, ^{238}U. Measurements were made using a low background gamma spectrometer with an HPGe detector (BE3830 Canberra/Mirion) with a relative efficiency of 34%. The uncertainties of the measurements did not exceed 10%.

PCA was performed for 27 samples and 6 variables (topsoil horizons with high organic matter content were omitted in the analysis). PCA was done in the Statgraphics Centurion 18 computer program. Table 1 shows the parameters of the PCA analysis conducted. The cumulative eigenvalue of the first two principal components was 5.2 and they explain 86.9% of the observed variance. According to the Kaiser criterion for further interpretation, it is enough to separate only the first two principal components (only they have an eigenvalue greater than one).

Table 1.Principal Components Analysis

Component Number	*Eigenvalue*	*Percent of Variance*	*Cumulative Percentage*
1	**3.73442**	62.240	62.240
2	**1.48167**	24.694	**86.935**
3	0.456711	7.612	94.547
4	0.254779	4.246	98.793
5	0.0526049	0.877	99.670
6	0.0198177	0.330	100.000

The PCA (Figure 1) carried out on the results obtained clearly separated the tested samples according to the type of ash from which they were created (ash from bituminous coal W1, W2, L and lignite B1, B2, K) and the disposal sites at which they were collected (W1 and W2 and B1 and B2, respectively, are samples from the same disposal sites). At the same time, it can be noticed that soils formed on ashes from hard bituminous coal-fired power

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plants contain more of all tested radioisotopes, including a particularly large amount of ^{40}K, while soils formed on ashes from lignite have relatively low gamma isotope contents, with the exception of ^{238}U in four samples from location "B", where this content was the highest of all tested samples. At the same time, PCA allowed us to notice that the density and activity of ^{40}K are quite well correlated, and the activities of the tested isotopes from the uranium-radium and thorium series are also correlated. One W2 sample, which clearly distinguished itself from the others, had a very high density and relatively low activities of the radioisotopes tested. Since this is a sample taken from a depth of between 1 and 20cm, it may indicate that the soil in this place was perhaps covered with a layer of sand-rich soil brought from outside.

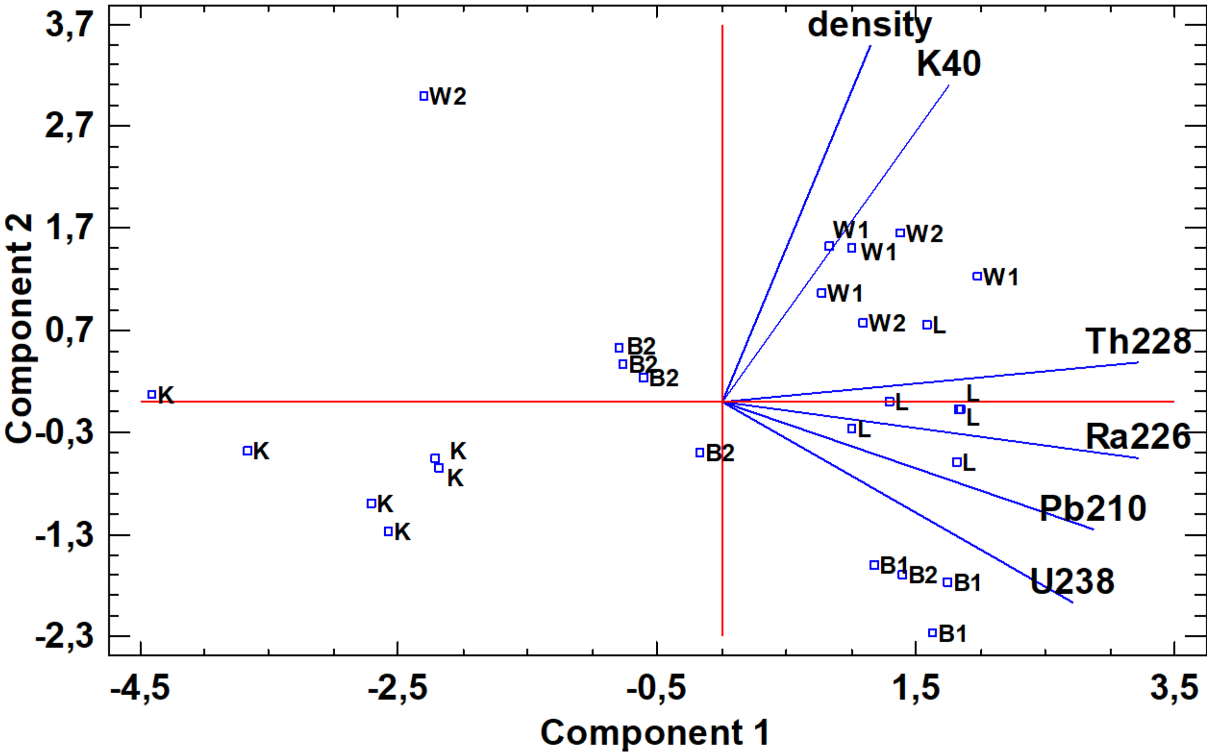

Figure 1. Biplot of the principal component analysis. K40, Th228, Ra226, Pb210, U238 are the activity in Bq·kg^{-1}, density refers to the soil prepared for measurement in g·cm^{-1}, W1, W2 and L are samples from power plants burning bituminous coal, B1, B2 and K are samples from power plants burning lignite.

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ENERGY FUELS ENVIRONMENT EFE2024
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Overall safety evaluation of a nuclear retrofit based on generation III/III+ nuclear reactor - case study

Tomasz Bury[1,*]

Keywords: nuclear retrofit, AP-1000, passive safety, safety evaluation

ABSTRACT

The presented results are a part of research activities within the framework of the DEsire project. The project analyzes a Coal-to-Nuclear energy transition paths [1]. Coal-to-Nuclear is an investment path assuming the construction of a nuclear unit with partial use of the infrastructure of the existing coal unit as part of the investment. The arguments for this are: limiting investment outlays, construction time limitation (not always), use of human capital, and social aspects, i.e. reducing the risk of recession in regions where energy activities are carried out.

Four paths for a nuclear retrofit are considered within the DEsire project: greenfield, brownfield, direct, and indirect. The project considered the possibility of applying the above-mentioned nuclear retrofit options to over a hundred existing power units in Poland. The assessment of readiness for retrofit was based on a number of technical [2] and safety criteria [3]. The analysis took into account the possibility of replacing existing heat sources with nuclear reactors of generations III, III+, and IV.

The safety analysis conducted by the Institute of Nuclear Chemistry and Technology in Warsaw took into account extended safety aspects specific to the location and nuclear reactor, including formal requirements and recommendations (seismic activity, floods, mines, airports, military facilities), potential nuclear threats to the unit's personnel and the local population (population density), applied solutions for the safety systems of the reactor itself, the thermal cycle of the steam turbine and auxiliary infrastructure, management of spent nuclear fuel and radioactive waste.

This work analyzed the nuclear retrofit of the Kozienice power plant, which received first place in the evaluation ranking due to safety criteria. The current installed capacity at the Kozienice power plant is 4.02 GWe. As part of the retrofit, it is planned to install from 2.3 GWe to 3.2 GWe in nuclear units. It was assumed that two nuclear units with the AP-1000 pressurized water reactors would be built in the examined location as part of the brownfield retrofit path. The conducted safety analysis covers technical safety aspects related to the selected nuclear reactor technology and issues related to the generation of radioactive waste, in particular spent nuclear fuel. Technical aspects of safety were analyzed based on the detailed technical characteristics of the nuclear power plant with the AP-1000 reactor, including comparing the most important indicators with the requirements set by legal regulations. The waste management analysis was based on design data, and in the case of spent fuel management, available operational data was also used.

The assessment of the technical safety aspects of the AP-1000 reactor is based on the results of a series of simulations of selected accident scenarios, during which the maintenance of basic safety functions by the system, i.e. criticality control, radionuclide isolation and nuclear fuel cooling, was examined. One of the analyzed failure scenarios was a complete loss of electricity supply. In this scope of analysis, the tested system, as passively safe, shows very good indicators confirming a high level of safety.

The analysis of the management of radioactive waste and spent nuclear fuel also indicates a high level of efficiency and safety of the system under consideration.

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Energy transition: insights into the future of the Polish power system until 2050

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Keywords: power system, modeling, CO_2 emission reduction, renewables, nuclear power

ABSTRACT

The energy transition carried out toward achieving the goal of climate neutrality in 2050 will require further extensive changes in the Polish power system. Electricity production in Poland is still largely based on conventional sources, mainly hard coal and lignite. Despite the fact that in recent years their share of electricity production has declined significantly (in 2023 it was 63%), the starting point of the Polish power system is still more difficult compared to other less coal-dependent European power systems. The way to achieve this goal is to further replace fossil fuel-based technologies with zero-emission ones, notably using renewable energy sources.

The study was carried out in the direction of optimizing the national structure of capacity and electricity generation, with the main goal of achieving at least a 95% reduction in CO_2 emissions by 2050 (the acceptable level of CO_2 emissions in 2050 was 10 Mt). The study considered a nuclear scenario, which assumed investments in nuclear energy technologies and an increasing share of renewable energy sources. The research used the TIMES-PL model, which minimizes the total cost of the system over the analyzed time horizon taking into account a number of constraints such as technical, economic and environmental.

The results show that in the analyzed time horizon, the required CO_2 emissions target is feasible (CO_2 emissions in 2050 amounted to 5.4 Mt), but it will require:

- Approximately 56 GW in renewable energy technologies. The share of electricity from renewables in 2050 will be about 59%. Wind power plants will play a major role in this production.
- More than 10 GW in nuclear power plants, with the first two units commissioned by 2035 (assumptions consistent with the Energy Policy of Poland until 2040). Nuclear power plants will help secure the system's operation (replacing aging coal-fired units operating at the system's load base). The calculated capacity factor of nuclear power plants exceeds 90%.
- Approximately 9 GW in gas technologies (particularly CCGT and OCGT gas-fired power plants). The use of these technologies increases the flexibility of power system operation. Their main role will be to provide sufficient regulatory and reserve capacities.
- More than 5 GW in energy storage technologies (including pumped-storage hydro power plants) which are capable of operating in generation and demand modes. Such technologies will be used in daily and seasonal balancing of the power system.

The authors are fully aware that the work does not fully cover the topic and should be considered as an introduction to the development of a possible path for the transition of the Polish power system until 2050. Further research should be carried out in the direction of verifying the limits of power distribution in the grid for a given generation structure of the system.

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Heat transfer intensity in the magnetic field dependence on a type of nanofluid

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Keywords: heat transfer, magnetic field, silver nanofluids, copper oxide nanofluid, numerical analysis, single- and two-phase approach

ABSTRACT

Presented work concentrated on influence of type of nanofluid on the heat transfer process in a magnetic field. Numerical analysis of silver and copper oxide nanofluids thermomagnetic convection was discussed from two points of view single- and two-phase ones. Comsol Multiphysics software was used to obtain the results in two configurations of magnetic field, which were also compared with own experimental data. The presence of silver nanofluids in an adverse and favourable magnetic induction gradient caused a slight improvement of heat transfer compared with water. The copper oxide in favourable configuration caused intensification of the convective heat transfer of about 13%.

Introduction

It is well known that nanofluids have gained their popularity as heat carriers due to improved thermal properties [1]. Therefore, to design a nanofluid for particular applications an attention should be put on selection of its components. The most common base fluid is water [2], which properties can be easily found. The properties of nanoparticles strongly depend on a type, shape and of material used.

The situation is even more complex when it comes to analysis of processes occurring in the magnetic field, because in addition to thermal properties, the magnetic one becomes important. When the nanofluid is treated as a single phase, the unique properties of particular components are 'merged' into properties of dominant phase. Therefore, presented research was conducted with special care devoted to checking of influence of properties of nanofluids components on the studied phenomenon.

Analyses were conducted for water-silver and water-copper oxide nanofluids at two configurations of magnetic field adverse (P1) and favourable (P2) from the heat transfer point of view.

Numerical analysis

In the presented work two approaches to numerical analysis of nanofluid heat transfer were conducted: single- and two-phase ones. The single-phase approach takes into account averaged properties of nanofluid components, while the two-phase one analyses both phases separately. The Comsol Multiphysics software was used to solve the mass, momentum and energy conservation equations. In the single-phase approach, Euler method of fluid analysis was applied, while in the two-phase approach, Euler-Euler one was applied. The numerical analysis reproduced the experimental conditions (nanoparticle concentration, thermal and magnetic) [3].

In Figure 1 the ratio of the Nusselt number and the Nusselt number without magnetic field as a function of the thermomagnetic Rayleigh number is shown for water and both analysed nanofluids at two magnetic field configurations (adverse P1 and favourable P2).

The magnetic field influences the heat transfer intensity in dependence on its configuration. The adverse magnetic induction gradient reduces the heat transfer process, while the favourable one intensifies it. The addition of copper oxide nanoparticles caused

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the largest increase in the heat transfer process and the least reduction in thermal convection. The addition of silver nanoparticles improves the heat transfer process in comparison to water.

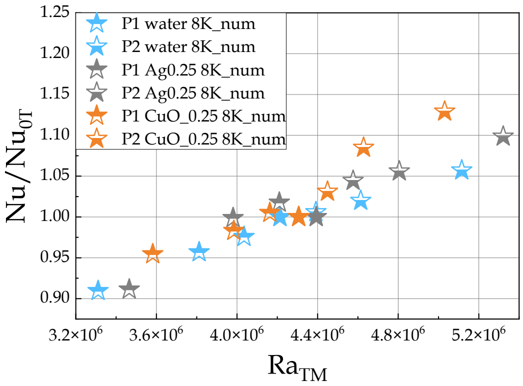

Figure 1. Values of the Nu/Nu$_{0T}$ *ratio at both magnetic field configurations*

Conclusions

The influence of nanoparticle addition and magnetic field application on thermal convection of water was analysed. The configuration of magnetic field is important because of the adverse or favourable impact on thermal convection. It has been shown that addition of copper oxide nanoparticles has higher influence on the thermal convection than the silver ones due their thermal and magnetic properties.

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Efficiency of a nuclear fuel utilization for contemporary and future nuclear reactor technologies

Tomasz Bury[1,*]

Keywords: nuclear fuel, fuel burnup, spent fuel, nuclear reactor technologies

ABSTRACT

According to data from the International Atomic Energy Agency in Vienna [1], there are currently 416 nuclear power reactors operating in the world, which represent 7 reactor technologies and belong to generations II, III, III+ and IV. All these reactors provide heat sources for the thermodynamic Rankine steam cycle. The thermal efficiency of such a cycle is defined as the electrical energy divided by the heat supplied to the cycle. In the case of conventional power plants and power plants using biomass or solar energy as primary energy sources, the energy efficiency of the power plant can most often be calculated as the quotient of electrical power and the chemical energy flow of the fuel, or more generally the primary energy flow. The energy efficiency of a nuclear power plant is basically defined as the thermal efficiency of a thermodynamic cycle: as the quotient of the electricity generated and the heat supplied to the cycle. However, such a definition does not make it possible to assess the degree of use of nuclear fuel. Due to the method of feeding reactors with nuclear fuel, the parameter that determines the degree of nuclear fuel utilization is its burn-up. This quantity is defined as the amount of heat obtained relative to a unit of mass, the so-called heavy metal (uranium). Therefore, the higher the value of this parameter, the more effective the use of nuclear fuel. However, direct comparison of nuclear fuel burn-up for different nuclear reactors does not allow for a rational comparison of different reactor technologies.

All nuclear reactor technologies currently in operation have been characterized in terms of the fuel cycles used. As part of this work, a comparison was carried out based on the unit amount of spent nuclear fuel related to the electricity produced over the entire life of the reactor. Data for calculations come from the Power Reactor Information System database [1] for generation II, III and III+ reactors, where available. Calculations for some of the analyzed generation III+ and IV reactors were based on technical specifications of technology suppliers.

A separate part of the work was devoted to the issue of reprocessing of spent nuclear fuel and its impact on the efficiency of fuel use.

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ENERGY FUELS ENVIRONMENT EFE2024
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Methodology for identifying hydrogen in the chemical composition of unidentified gaseous fuels during the measurement of their calorific value and heat of combustion using an innovative gas calorimeter

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Keywords: non-normative gases, calorimeter, heat of combustion, calorific value, hydrogen

ABSTRACT

The issue of measuring and determining the calorific value of fuels is associated with the thermodynamic analysis of the effects of the combustion process aimed at determining the amount of heat released to the environment. Currently, there are several methods for determining the calorific value of fuels, and these are methodologically related to the type of fuel being analyzed. These methods are complex and require the use of specialized measuring equipment. Current technological processes related to generating energy from gaseous fuels and the production processes of gaseous biofuels require constant quality control of the fuel. Current information about the basic parameters of gases is necessary for the efficient acquisition of energy during the combustion of these fuels or for high process efficiency in the production technology of gaseous biofuels such as fermentation, co-fermentation, biomass gasification, and waste gasification.

Industrial processes for obtaining alternative gaseous fuels are particularly dependent on the quality of the input material. This is especially true for gasification and pyrolysis installations, where the input consists of materials with diverse physicochemical properties and structures. Such diversity, forces companies to segregate these materials before processing. Despite this, the input material still determines the quality of the gasification and pyrolysis processes, which directly affects the resulting fuel in the form of syngas. Its energy quality is closely related to its chemical composition, which is linked to the reactions occurring during gasification or pyrolysis. Therefore, it is necessary to continuously monitor the quality of the obtained gaseous fuel to quickly adjust the ongoing processing operations.

The proposed device is universal in terms of its use with various, often initially unidentified types of gases. The accuracy of the calorimeter's measurement system has been verified in laboratory tests, which focused on measuring the calorific value and heat of combustion of known types of gases. To identify the considered gaseous fuel, in addition to the information collected from the sensors embedded in the calorimeter, a flue gas analyzer will be necessary to determine the chemical composition of the exhaust gases. By combining these two measurement devices, a range of information will be obtained, such as the heat of combustion, calorific value, evaluation of combustion process efficiency, and determination of pollutant emissions into the atmosphere related to the combustion of the considered fuel. Further analysis of combustion process parameters, combined with advanced measurement and analytical techniques, allows for the assessment of the hydrogen content in the gaseous fuel. This approach not only increases efficiency but also helps control pollutant emissions

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and improve the safety of combustion processes. By adjusting combustion process conditions, such as temperature, pressure, excess air coefficient, and observing changes in the composition of exhaust gases, it is possible to determine how different parameters affect hydrogen combustion. Optimizing these parameters can help in accurately determining the hydrogen content in the fuel.

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Large-scale heat storage

Andrzej Gołdasz[1],*, Artur Szajding[1], Karol Sztekler[1], Ewelina Radomska[1], Marta Kuta[1]

Keywords: heat storage, phase change material

ABSTRACT

Heat storage on a large scale remains a partially unresolved technical challenge. In this work, we present a solution for a mobile heat storage system called the Mobile Modular Container (MMC) with a thermal capacity of 2 MWh, based on phase change materials (PCMs). The MMC is designed in a housing similar in size to a 6-meter container, allowing for transport using a standard truck or tractor unit (see Figure 1).

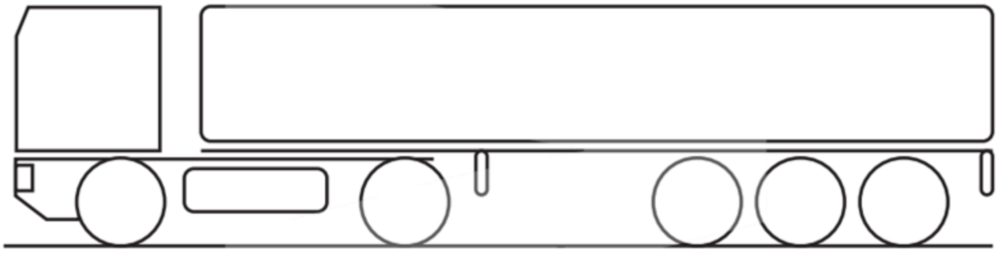

Figure 1. MMC in container housing

The mobile heat storage system will be charged with waste heat at a temperature of approximately 95°C. Discharging the heat storage system—i.e., the water temperature at the outlet for the recipient—should be around 70°C. The PCM material considered for this solution is A82, produced by Phase Change Material Products Limited. The properties of the PCM material are summarized in Table 1.

Table 1. Properties of the A82 material

Parametr	Value	Unit
Phase change enthalpy	240	kJ/kg
Melting temperature	82	°C
Specific heat capacity	2,2	kJ/(kgK)
Density	930	kg/m^3
Thermal conductivity coefficient	0,23	W/(mK)

Despite using various container sizes and geometries for heat storage, the low thermal conductivity of phase change materials remains a significant challenge during construction. This limitation results in slow heat exchange between the fluid and PCM, leading to extended charging and discharging times for heat storage systems [1]. Numerous articles [2-4] have explored methods and techniques to improve heat exchange rates between the heat transfer fluid (HTF) and PCM. Some approaches to enhance heat exchange in PCM-based heat storage systems include::

- Ribbed Surfaces: Increasing the heat exchange surface area using ribbed structures.
- Nanoparticle-Enhanced PCM: Combining heat exchange surface expansion with the

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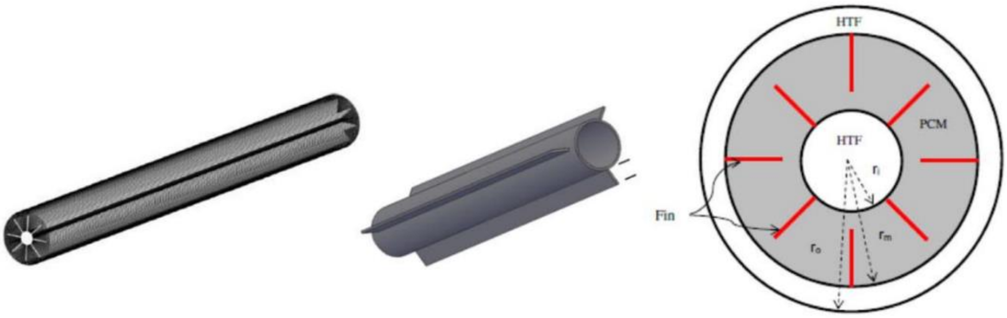
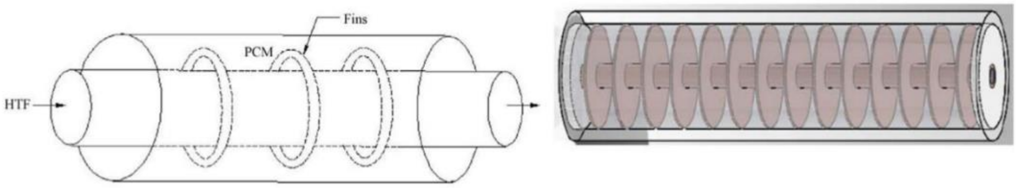
addition of nanoparticles to the PCM.
- Porous or Metallic Foam Materials: Using porous or metallic foam materials.

To improve heat exchange in PCMs, ribbed structures are commonly employed due to their simplicity and ease of implementation in thermal energy storage (TES) systems [5]. Both longitudinal and transverse ribs, as well as needle-like ribs, are used (see Figure 2).

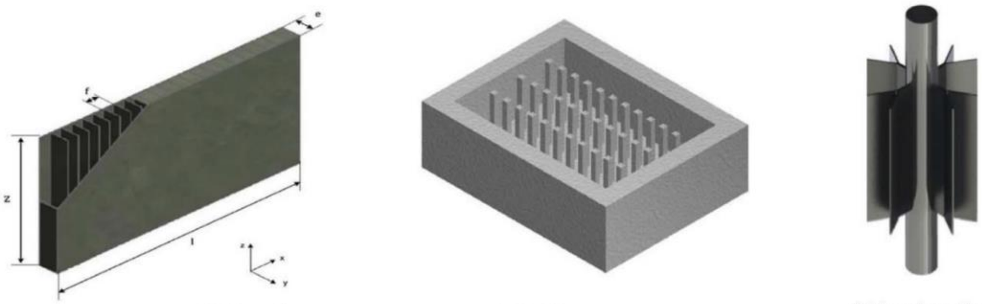


a) Longitudinal fins



b) Annular fins

c) Circular fins



d) Plates fins

e) Pins fins

f) Tree shape fins

Figure 2. Rib geometries used in PCM-based storage systems [6]

For our mobile heat storage system, which emphasizes mobility and modularity, we opted for a rectangular container shape to store the PCM. This design allows for a lower ratio of surface area occupied by the PCM storage to its thermal capacity. Additionally, it provides flexibility in floor dimensions, which is crucial for transportation. We incorporated a heat exchanger with copper tubes and additional aluminum fins. Numerical simulations guided the selection of fin size, thickness, and arrangement.

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ENERGY FUELS ENVIRONMENT EFE2024
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Characterization and Catalytic Performance of Manganese, Iron, Copper, and Nickel-Promoted Cenospheres in Selective Reduction of NO by Ammonia (SCR-NH_3)

Bogdan Samojeden[1,*], Dorota Duraczyńska[2], Monika Motak[1]

Keywords: cenospheres, SCR-NH_3, deNOx, fly ash

ABSTRACT

Cenospheres, gas-filled aluminosilicate spheres found in fly ash from power plants, possess valuable properties such as thermal insulation, frost resistance, and fire resistance. These properties make them useful across various industrial applications, prompting interest in their recovery and modification. This study examines the properties of gray and white cenospheres enhanced with manganese, iron, copper, and nickel ions using IR spectroscopy, X-ray diffraction, scanning electron microscopy, and textural analysis. The modified cenospheres were tested as catalysts in the selective catalytic reduction of NO by ammonia. Mn-modified cenospheres achieved the highest NO conversion rate of 95% but produced 270 ppm N_2O at 300°C. Copper-modified catalysts demonstrated the best performance with approximately 90% NO conversion at 250°C.

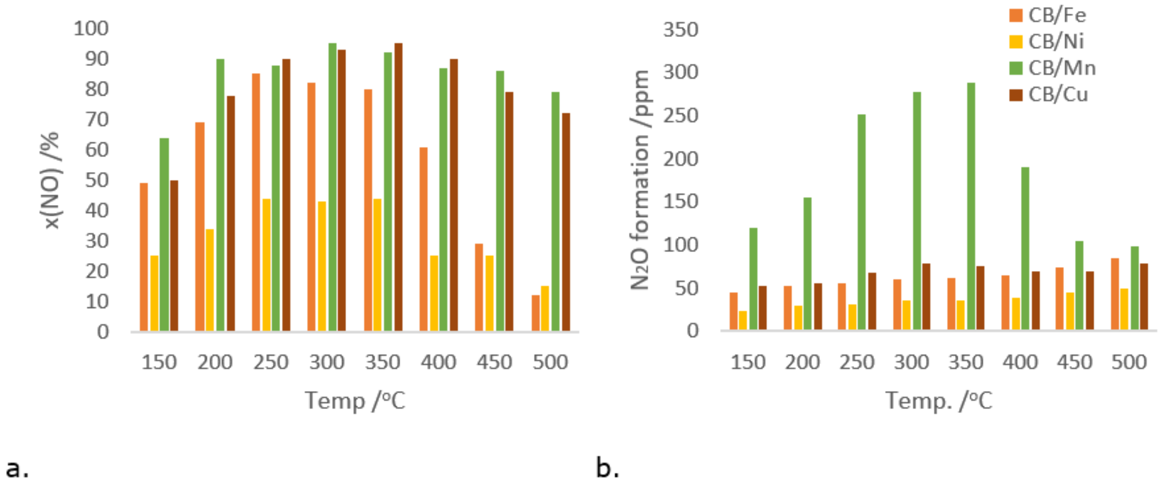

Figure 1. SCR-NH_3 results of testes catalysts: a. NO conversion; b. N_2O formation. Reaction conditions: [NO]=800 ppm, [NH_3]=800 ppm, O_2 = 5%, rest Ar, flow 100 ml/min

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Biocatalysts – glycerol case in large scale industry

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Keywords: biotechnology, glycerol, waste management, microorganisms

ABSTRACT

One of the new ideas of raw glycerol management is its conversion to lactic acid and other chemical compounds. The biotechnological method is based on the use of microorganisms as biocatalysts that are able to metabolize glycerin as a carbon source into other products, for example organic acids. This happens through fermentation.

Interestingly, lactic acid bacteria can be homo or heterofermentative, i.e., they can produce only one chemical compound or several - thanks to which we have control over fermentation and its products.

The aim of study was glycerol fermentation into lactic acid using microorganisms. During experiments growth of bacteria on liquid media with glycerol addition was tested. The density of cultures was measured using a DEN-1 densitometer (BioSan). Lactic acid bacteria (used for experiments) were selected strains from White Labs Pure (WLP): *Lactobacillus delbrueckii* [WLP 677] *(Ryc. 3)*, *Lactobacillus brevis* [WLP 672] *(Ryc. 1)* and from American Type Culture Collection (ATCC): *Lactobacillus rhamnosus* [ATCC 7469] *(Ryc. 4)*, *Lactobacillus plantarum* [ATCC 8014] *(Ryc. 5)* and *Lactobacillus leichmanii* [ATCC 7830] *(Ryc. 2)*. Bacteria were observed under the microscope before, during and after fermentation. The largest growth of bacteria on the medium with the addition of low and high concentrations of glycerol was obtained after two days, after which this number decreased in most measurements. The production of lactic acid during the bacteria growth in the MRS broth model medium was monitored by UV-Vis.

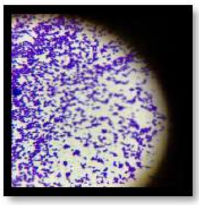
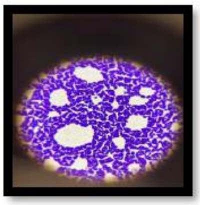


Fig. 1.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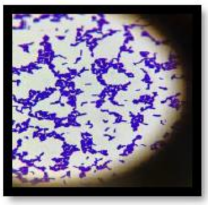
Fig. 3.

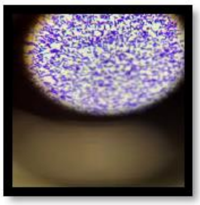
Fig. 4.

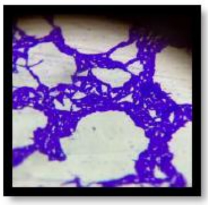
Fig. 5.

Based on the obtained results, it can be concluded that all of selected bacteria are a good biocatalyst in glycerol fermentation, but the best one is *L. plantarum*. One of the fermentation products is lactic acid according to the obtained UV-Vis spectra.

As a result, glycerol does not deactivate the bacterial environment, favors the growth of microorganisms, can be converted into organic compounds, and the final compounds obtained are mainly lactic acid.

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Development and Characterization of Vermiculite-Based Catalysts for SCR-NH_3: Efficiency at 300-450°C

Bogdan Samojeden[1]*, **Monika Motak**[1]

Keywords: vermiculite, SCR-NH_3, deNOx, Vermiculite-Based Catalysts

ABSTRACT

In the 21st century, the dynamic development of industrialized countries is observed, which provokes contemporary society to take action to protect the environment. Currently, a number of studies are being carried out to reduce emissions of nitrogen oxides, which are considered extremely harmful to both human health and the natural environment [1]. One of the methods is the reaction of selective catalytic reduction of nitrogen oxides with ammonia (SCR-NH_3) [2]. This method involves the reduction of nitrogen oxides by ammonia in the presence of a catalyst, forming nitrogen and water. Bearing in mind the problem of the temperature range of catalysts, the present work focuses on the development of a new catalyst that will achieve satisfactory efficiency already at temperatures of 300- 450°C. As the catalytic material, vermiculite modified with aluminum oxide was used, which was additionally impregnated with copper, iron and cerium ions. The best parameters were obtained for vermiculite modified with iron ions 3% and cerium ions 0.5%, resulting in a conversion rate of 80%. Analysis of the results of the conducted tests confirmed the possibility of using the described vermiculite as a catalyst in the reaction of selective catalytic reduction of nitrogen oxides with ammonia (SCR-NH_3).

Acknowledgments: This work were financed by Grant AGH 11.11.210.476

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Study on Corrosion Behaviour of Lead and its Alloys

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Keywords: alloys, corrosion, cyclic voltammetry (CV), electrochemical immittance spectroscopy (EIS), lead

ABSTRACT

Progressing electrification leads to development of manners of generation and storage of the electric energy. While lithium-ion batteries get more and more interest, subjects like their recycling and limited access to i.a. lithium deposits are being discussed. This inspire the search for alternative energy storages, such as hydrogen storage combined with fuel cells, post-lithium cells, or nickel-metal hydride ones. Another construction regaining attention is lead-acid battery. This is due to multiple factors, including efficiencies in both high and low temperatures, low cost and well-developed recycling technology. Despite of having many advantages, lead-acid batteries pose such challenges as sulphation (uncontrolled growing of lead sulphate crystals), gassing (oxygen and hydrogen evolution during charging) or corrosion of lead grids on which electrode material is suspended, the latter being subject of the study presented herein.

During the course of presented research the influence of temperature, sulphuric acid concentration and electrode material composition on electrode electrochemical behaviour were studied. Tests were conducted in 25°C in 3.0 – 5.0 M sulphuric acid (in 0.5 M steps), and in 5.0 M sulphuric acid, in 10°C, 30°C and 50°C. Pure (99.99%) lead, its binary alloy with antimony (ca. 4 wt%) complying to OT-4 industrial standard and ternary alloy with antimony and selenium (1,8 wt% Sb, 0,025 wt% Se) were used as electrode materials. Cyclic Voltammetry (CV) was used in order to determine potentials of red-ox reactions, preliminary estimate corrosion resistance and to simulate working conditions of lead-acid battery while Electrochemical Immittance Spectroscopy (EIS) provided information on possible mechanism of the corrosion phenomena occurring, as well as, the resistance of working electrode material against these processes. All studies were conducted in three electrode cell.

Figure 1. a) and b) shows fittings of spectra obtained in 5.0 M sulphuric acid, in 30°C, before (a) and after (b) CV measurements alongside with one-ports (OP) parts.

In the pictures one can see difference in third one-port – while before CV measurements it's semicircle, its shape changes to half of tear. The reason of that is presence of Gerischer diffusion element in Equivalent Circuit (EqC) in OP mentioned, indicating porosity of electrode.

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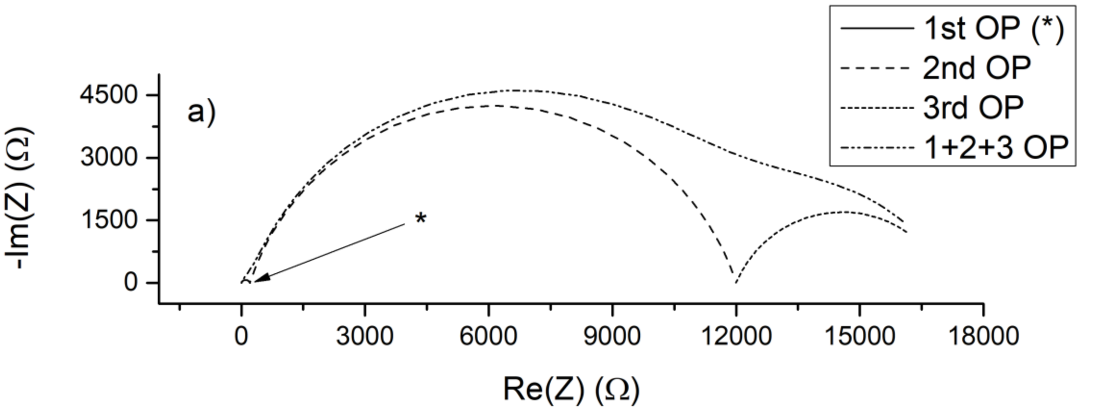

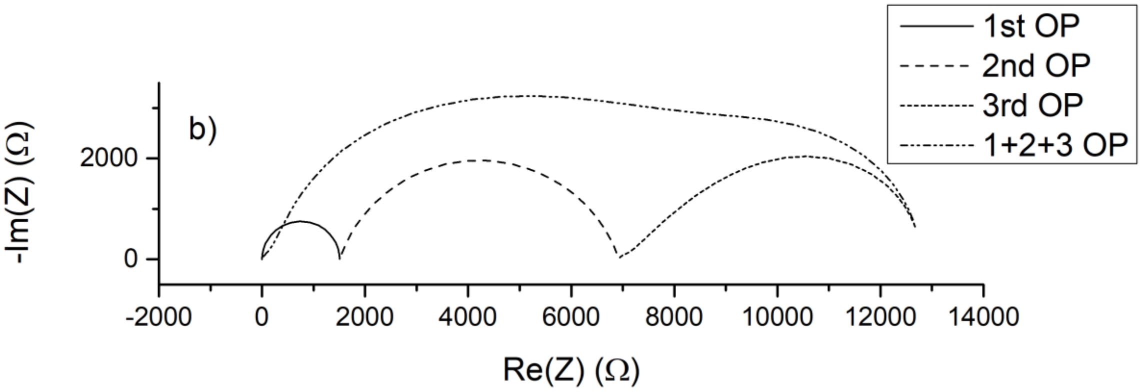

Figure 2. Fittings of spectra and its one-ports before (a) and after (b) CV measurements.

Figure 2. shows spectra of pure lead, lead-antimony alloy and lead-antimony-selenium alloy obtained in 4.0 M sulphuric acid, in 25°C.

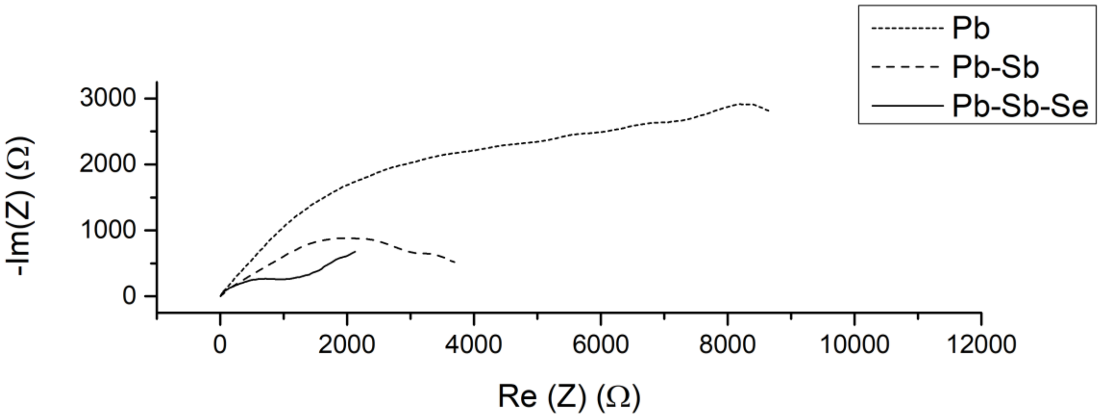

Figure 3. Spectra of pure lead and its alloys. Sulphuric acid concentration: 4.0 M, temperature: 25°C.

Corrosion resistance decreased in following series: pure lead, lead-antimony alloy, lead-selenium alloy. While using alloying agents might seem harmful, they improve mechanical properties of lead, or limit processes such as gassing mentioned above. [1, 2]

Corrosion resistance decreases as temperature raises. The least corrosion resistance was observed in 3.5 M sulphuric acid. This concentration corresponds with almost fully discharged battery, which is not often achieved in stationary nor mobile use of lead-acid battery. During prolonged storage it is advised to either maintain proper State of Charge, or store batteries without electrolyte.

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ENERGY FUELS ENVIRONMENT EFE2024

26-28 JUNE 2024, KRAKOW, POLAND

Prospective use of soils as a source of natural sorbents used in environmental decontamination from ^{137}Cs

Katarzyna Szarłowicz[1,*], Filip Jędrzejek[1], Marcin Stobiński[1], Barbara Kubica, Michał Skiba[2]

Keywords: ^{137}Cs, decontamination, natural sorbents, radioactivity

ABSTRACT

The contamination of ecosystems by radioactive isotopes, such as ^{137}Cs, poses significant environmental and public health risks. Addressing this issue requires the use of materials that are environmentally inert and preferably of natural origin. Taking into account these assumptions, this study investigates the potential of various soil types to serve as a natural sorbent for the decontamination of ^{137}Cs from affected environments. The research involves the separation of specific soil fractions that are capable of stably binding caesium within their structure.

The first stage of the research involved analysing ^{137}Cs concentrations in soil in two national parks: Tatra Mountains National Park and Karkonosze National Park. The goal was to identify soils with the highest accumulation of the radioisotope, possibly due to the presence of potential sorbent fractions that can form permanent caesium ion bonds with high resistance to environmental conditions such as leaching. National parks are strict protection areas, so the soil there is minimally affected by direct anthropogenic activity. Additionally, the presence of caesium in the soil structure should indicate good selectivity properties, as the sorption process occurs under natural environmental conditions.

Natural sorbents can be associated with both organic and mineral fractions of the soil. Inorganic sorbents, particularly clay minerals, are recognised for their high resistance and strong binding capabilities, which distinguish them from organic sorbents [1]. Clay minerals exhibit significant sorption capacities due to their high surface area, cation exchange capacity, and specific structural properties. These properties provide numerous adsorption sites and facilitate the formation of strong bonds with Cs ions, leading to effective immobilisation [2]. Therefore, this study also focusses on identifying sorbents within the mineral fraction of the soil. From selected environmental samples, an attempt was made to separate minerals classified as finely crystalline mica (in clay minerals type), e.g. dioctahedral vermiculite or smectites. Then, characterisation through X-ray diffraction was conducted. In addition, a study related to the quantitative presence of the cesium radionuclide was carried out in every soil fraction using gamma spectrometry.

In conclusion, this study underscores the potential of clay minerals as effective sorbents for ^{137}Cs decontamination, highlighting their role as a sustainable and practical solution in environmental remediation efforts. Integration of soil science and radiological safety offers a path to mitigate the impact of nuclear contamination and protect both human health and the environment. This approach offers a cost-effective and sustainable alternative to synthetic sorbents, contributing to the improved management of radioactive contamination in the environment. Further research is recommended to assess the long-term stability of ^{137}Cs immobilization and to optimize application methods.

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Impact of the EU „Fit for 55" package on the transformation of the district heating sector in Poland - key conclusions, costs and directions

Dorota Jeziorowska[1]

ABSTRACT

The paper presents key conclusions resulting from a multi-variant analysis of the impact of the "Fit for 55" package on the transformation of the district heating sector, which was carried out by the Polish Association of Professional Combined Heat and Power Plants. The trajectory of achieving climate neutrality by district heating systems is described, as well as its directions, necessary investment outlays and legislative recommendations. The conclusions resulting from the analysis of the potential and role of the Power to Heat technology are also described.

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ENERGY FUELS ENVIRONMENT EFE2024

26-28 JUNE 2024, KRAKOW, POLAND

Use of waste heat from natural gas compression processes

Michał Gołębiewski[1,*]

Keywords: gas compressor stations, waste heat, ORC system

ABSTRACT

Currently, Poland energy sector is primarily based on coal power plants, which produce over 69% of the country's electricity [1]. This is a significant problem for the country as its government has committed to phasing out coal use by 2035. This necessitates a rapid modernization of the energy sector. One possible transitional solution could be combined cycle gas plants using natural gas as fuel. This energy carrier can reduce CO2 emissions by almost 50% compared to hard coal [2]. This will allow for a reduction in the impact of the electricity production sector on environmental pollution and climate change. Additionally, devices such as gas turbines can better cooperate with unstable renewable energy sources in terms of power regulation. Another benefit of using gas fuel is its easier transportation compared to coal. This enables the use of distributed energy systems based on gas engines or turbines. Local production of electricity and heat allows for a reduction in energy losses in power transmission lines.

The geopolitical situation in Europe in the 2020s has significantly affected the energy markets of the countries within it. The most significant impact was Russia attack on Ukraine and the subsequent global boycott of the aggressor. From an energy perspective, this mainly involved limiting the import of fossil fuels from Russia. The result of such actions was the complete halt of oil and natural gas supplies from that country. This necessitated the search for new suppliers of this raw material. In the case of Poland, the solution to this problem turned out to be investments such as the LNG (Liquefied Natural Gas) terminal and the Baltic Pipe gas pipeline. These allow for independence from Russian raw material supplies. Nonetheless, the current situation may require careful utilization of this resource. This problem could be exacerbated during the modernization of the national energy system, where increased demand for this raw material will require more efficient usage of its limited resources.

The gas system is based on a network of gas pipelines, reduction stations, and gas compressor stations that enforce the flow of the raw material and the further operation of the system. Consequently, the pressure increase process is one of the elements that consume energy and generate losses. The recovery of waste energy from gas compressor stations has already been addressed in terms of the heat from the exhaust gases of gas turbines driving natural gas compressors [3]. The theoretical analysis in the mentioned study concerned the use of the ORC (Organic Rankine Cycle) system. The authors showed that, depending on the turbine used, energy recovery could reach up to 30% of the turbine's power.

Waste energy from the gas compression process is not only the heat from the exhaust of the device driving the compressor. The gas compression process involves raising the temperature of the compressed gas. Therefore, the temperature of the gas at the discharge port of the compressor can exceed 100°C and must be reduced to ambient temperature to be transported through the pipeline. The standard solution is to use gas coolers where the heat from the compression process is lost to the environment. In the presented study, an analysis of the ORC system utilizing low-temperature heat from the compression process was carried out (Fig. 1). Possible working fluids were identified for use within the available temperature range, and the theoretical efficiency values of the

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system were determined. It was shown that with the current consumption of natural gas in the country, it is possible to recover over 20 GWh of electricity from the thermal energy of compressed gas alone. This value could increase with the higher consumption of natural gas in the case of modernizing the energy sector with devices powered by this fuel.

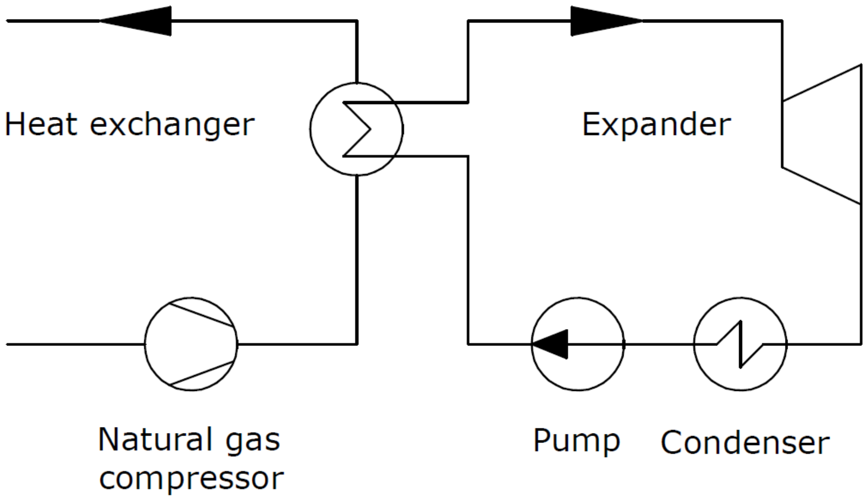

Figure 1. Diagram of the heat recovery system for the compression process based on ORC

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Uranium extraction in a system using semi-permeable membranes

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Keywords: uranium extraction, waste material disposal, uranium leaching, fly ashes

ABSTRACT

This study presents a new method for uranium extraction using a semi-permeable membrane. The method is particularly useful for materials that are difficult to leach using standard procedures, often found as waste materials with a physically and chemically challenging matrix. It is dedicated to materials with a high dusty fraction content that form suspensions with the leaching medium, such as coal ash, phosphogypsum, and copper mining waste. This method potentially creates opportunities to use various waste materials as a source of uranium for nuclear fuel production.

A significant example of this type of material in Poland is waste from coal combustion. Hard coal is the main source of electricity in Poland. According to data from the Central Statistical Office, the average consumption of thermal coal in Poland in recent years is more than 70 million tons [1]. This results in an average annual production of about 4 million tons of fly ash. Globally, up to 420 million tons of ash are produced annually, primarily by China and the US [2].

Energy-used coal deposits contain trace concentrations of naturally occurring radioactive isotopes, including Th-232, U-235, U-238, and their decay products. During combustion, mobile fractions of radionuclides or their condensates are usually retained in fine-grained ash particles, with equivalent amounts remaining directly bound to bottom ash. This technological process results in a concentration of uranium in ash that is 5 to 10 times higher than in the original raw material. Thus, fly ash and bottom ash can potentially serve as sources of valuable isotopes [3].

Considering the scale of the coal industry, these materials could be a viable alternative source of nuclear fuel. The development of this technology aligns with plans for the construction of Poland's nuclear power industry and can help minimize the consumption of raw materials and waste, supporting a closed-loop energy industry. However, the idea's complexity arises from technological challenges related to the relatively low uranium content, the high proportion of chemically competitive elements, and the volumetric predominance of the dusty fraction, which forms suspensions during leaching.

The purpose of this work is to present the potential of this new method for application in this area. Preliminary studies were carried out on fly ash samples, where uranium fractions were successfully obtained by leaching with a concentrated solution of nitric acid (V). The study includes preliminary findings on extraction efficiency and an experiment on process optimization (e.g., kinetics). A schematic of the extraction system is presented in Figure 1.

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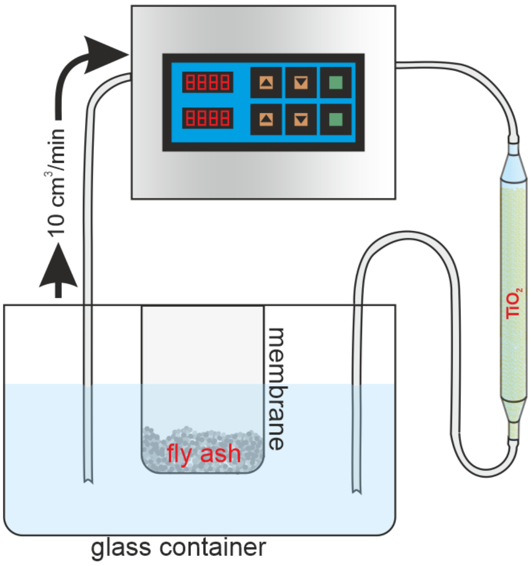

Figure 1. Diagram of the experimental setup

Most research on uranium extraction processes has focused on using bottom ash, which is less demanding than fly ash. This work, however, focuses on the dust fraction of waste, which is more challenging to leach. To consider the possible economic viability of the process, maximum recovery must be ensured for all fractions, including those with the smallest particle diameters. The results presented here represent an important step toward the commercialisation of this solution. By addressing the most challenging aspects of uranium extraction from dusty fractions, this method could significantly contribute to the sustainability and efficiency of nuclear fuel production from all sorts of waste.

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Optimization and management of an integrated energy system

Katarzyna Gdowska[1]*, Roger Książek[1], Radosław Kapłan[1]

ABSTRACT

This article presents advanced methods for optimizing and managing an integrated energy system using photovoltaic panels, energy storage, and hydrogen technology. The article outlines the goals of this system, which include minimizing costs and losses by effectively forecasting energy demand and managing the flow of energy between different sources and storage facilities.

The authors propose the analyzed energy system consisting of photovoltaic panels and the power grid, with energy stored in three types of storage: high-efficiency batteries, hydrogen storage, and thermal storage. The main objective of controlling the system is to minimize the annual operating costs by choosing the most efficient path for the energy flow at any given time, considering the availability and losses associated with each source. The article shows that the system must decide on using energy from photovoltaic panels, the grid, batteries, and hydrogen technology, considering weather conditions and domestic hot water demand. In addition, the system manages the energy flow between storage units, optimizing the order of their discharge to minimize losses. This considers adverse weather conditions, low battery energy levels, limited electricity demand, and increased heating demand.

The authors also propose using the weather forecast five days in advance, which allows for more accurate forecasting of energy needs. Finally, the article presents a control system that not only ensures energy delivery to consumers but also minimizes losses and operating costs, considering different energy sources and storage. This requires continuous monitoring and real-time optimization, which is a complex task.

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ENERGY FUELS ENVIRONMENT EFE2024
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Role of medium temperature protonic conductors in Power-to-X ecosystem

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Keywords: Power-to-X, green hydrogen, green ammonia, CO_2 reuse, medium temperature protonic conductors

ABSTRACT

European Green Deal – the nowadays implemented solution for global climate changes is focusing in its foresight on reaching the carbon neutrality till 2050. This ambitious goal can be realized by two main strategies related **to decarbonization of economy and by means of carbon dioxide capture and sequestering** including **extraction** of this gas **from natural deposits such as sea water**. Due to the nature of the modern society this can be achieved only by the introduction and deployment of technological innovations believed, according to **Agenda for Sustainable Development**, to be key dimension in efforts to achieve the environmental and growth objectives. In terms of the energetic transformation planned these activities should coherently address both the issue of the efficient and environment-smart utilisation and/or storage of the **excessive renewable electric power**, as well as, manufacturing of various chemicals in a 'green' manner. This, under the premise of the availability of "cheap electrons" from renewable electricity will make the electrochemical processes such as production of hydrogen, synthesis of ammonia or carbon dioxide reduction while exhibiting significantly differing technological maturity levels subjects of not only intensive scientific research, but as well, are a matter of various policies.

In terms of **hydrogen** production EU has implemented strong instruments such as its Delegated Acts on Renewable Hydrogen with the objective of installing at least 10 GW of renewable hydrogen production capacity and the **REPowerEU** plan targeting an additional installation of at least 40 GW of electrolysis capacity for renewable hydrogen by 2030. This illustrates that the EU deems hydrogen a highly efficient energy carrier that is in demand as a substrate for the chemical industry, including the manufacturing of ammonia, methanol, and synthetic fuels. Furthermore, the hydrogen-based energy transformation will also apply to other industrial sectors, such as metallurgy, glass, or cement.

Green ammonia is assumed to be an important part of the European hydrogen economy as it is relatively easy and cheap to both manufacture and deploy. In this terms Europe can make use of existing infrastructure. It is well as, believed to be one of the future hydrogen carriers as, when compared to pure hydrogen, it is easier and cheaper to store, and transport and it can be readily "cracked" and purified to give hydrogen gas when required. The mostly recognized way of making green ammonia is by typical Haber Bosch process but using hydrogen from water electrolysis and nitrogen separated from the air. On the other hand the nitrogen molecule (N_2) with triple bond is an extremely inert (even more than CO_2 mentioned below) reactant that requires special means of activation through strong adsorption at the electrocatalytic interface. Thus electrocatalytic studies can yield in the development of the solutions that would effectively break the nitrogen nitrogen bond to successfully drive the **N2RR** – a process of molecular nitrogen electroeduction to ammonia. Finally, it is worth to stress that according to *Climate Action Network Europe,* breakthrough in the NH_3-synthesis technology is crucial for a sustainable

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future.

Carbon dioxide reduction could provide an alternative source of fuels and chemicals, partially displacing fossil fuels in sectors that are more difficult to decarbonise. Unfortunately, the **CO2RR** (CO_2 Reduction Reaction) is a very inert process that requires breaking the double C=O bond in the stable CO_2 molecule. A common feature is the appearance of the poisoning or passivating CO-intermediate. Independently of this limitations the process is assumed to be an effective mean of the sequestration of this GHG yielding in such valuable products as carbon monoxide, formic acid, alcohols or (predominantly in terms of high temperature processes) hydrocarbons. While the theoretical background of all these processes is well established no industrially-scaled process of low temperature CO_2 electrolysis was developed till now. Moreover, their high temperature counterparts are limited to either pilots or just introduced technologies delivering the ultra-pure carbon monoxide. The strategy to generate high-energy molecules based (sustainable fuels) derived from CO_2 and water has recently been considered as one of the important long-term solution to address the problems of the climate change effects as well as to provide potentially a viable alternative to fossil fuels.

Despite of their different electrochemistry and catalyst/reactants expectations all three affordable and clean energy related processes mentioned above not only belong to the same **Power-to-X ecosystem**, but aw well from the technical point of view share a set of very similar crucial problems. These i.a can be attributed to: i) need of the improvement of the activity, selectivity, durability and lifetime of the catalytic electrode and the electrochemical devices utilizing it; ii) limited availability of some important catalytic materials confirmed by e.g. lists of Critical Raw Materials and Strategic Raw Materials; iii) issues of recyclability, environmental impact and sustainability. Therefore, the further developments expected should result in significant improvements in efficiency, system lifetime, intelligent refurbishment, and recycling concepts, all of which will lead to a parallel reduction in the total cost of both the electrochemical processes and their respective products.

Therefore, the use of the **medium temperature appointed systems** can be an interesting compromise between the increase of the catalytic activity of materials and the reduction of their poisoning fragility achieved upon the increase of the operational temperature below the 150-180 $_o$C threshold characterizing low temperature designs and material degradation issues significantly growing for high temperature systems (>600 $_o$C). While initiating the survey for a medium temperature cell design suitable for the needs defined above one should consider that whereas both the high temperature [1] and low [2] operational range of electrochemical devices is widely explored the successful application of the **protonic conductors operating between 200 and 450 $_o$C is still problematic** [3]. Therefore, a bunch of research efforts was and still is focused on the development of novel types of the protonic conductors being able to work in the desired temperature range. Despite of the polymeric materials various inorganic systems including ceramic mesoporous, and first of all, glassy protonic conductors are considered as potential electrolytes, as well as, their composites [4,5].

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Studies on environmental pollutants and their distribution in waters and bottom sediments

M. Macherzyński[1], J. Górecki[1], K. Styszko[1], J. Gołaś[1]

ABSTRACT

Analytical research on water pollution and water ecosystems, together with research on the changes taking place in these ecosystems, is an important topic that was undertaken by employees of the Department of Environmental Sciences, and later the Department of Environmental Sciences in Energy, led by Prof. Janusz Gołaś.

The object of study was surface water, river sediments as well as physicochemical transformations taking place at the interface of these phases (environments). The research included the development of new analytical methods, such as the analysis of total mercury using cold vapor atomic absorption spectrometry (CV-AAS) in complex environmental samples such as bottom sediment or fish tissues, and methylmercury in tissue samples using a gas chromatography station with the analysis of cold mercury vapor using atomic fluorescence spectrometry (Pyr-GC/AFS).

Research conducted using a wide range of methods (granulometric analysis, BET, UV-Vis, AAS, ICP-OES, XRD, XRF, IC, HPLC, radionuclide determinations and others) was mainly aimed at describing the processes of accumulation and transformation of chemical compounds in sediments and waters of retention reservoirs and rivers.

For four years, the department's employees coordinated the work of a team participating in a large research project regarding the Dobczyce Reservoir, which supplies approximately 60% of the city of Krakow with drinking water. The analyzes conducted in a international, multi-institutional and interdisciplinary (analysts, chemists, radiochemists, geologists, sedimentologists, biologists, remote sensing specialists) group contributed to the description and better understanding of the ecosystem of this reservoir. A number of works were carried out: determining the reference state and identifying potential sources of origin and release of selected groups of chemical compounds (including hazardous ones) from the tested reservoir. For example, the content of heavy metals, including Ba, Cr, Pb, Cu, Cd, Zn and inorganic components such as clay minerals and suspensions of Fe, Mn, Al and Ca compounds, which participate in the accumulation processes in sediments, was described. Seasonal variability of anion concentrations in water and pore water in the sediment was monitored. Studies were carried out on the quality of the water of the Raba River directly upstream of the Dobczyce Reservoir, including the identification of threats related to littering, silting and overgrowing of the river. The sorption capacity of bottom sediments was tested for the possibility of binding heavy metals and pharmaceuticals depending on their composition and place of collection from the reservoir – at that time original research related to the emerging contaminants in` waters. The changes taking place at the interface between bottom water and sediment (pore water) were studied, i.e. sorption or, in a broader sense, the accumulation of individual pollutants in sediments and their immobilization in the sediment (equilibrium at the interface between pore water and sediment) in the phase of early diagenesis (rock-forming process). This indicated research will be described in more detail during the presentation.

Other groups from the team also conducted research on radionuclides, surfactants, biogenic substances and the seasonal content of selected microorganisms.

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The experience gained allowed the group of prof. Janusz Gołaś to participate in other projects related to the aquatic environment, such as Integrated Research UE Project AQUATERRA, where mercury was measured in water, sediments and fish.

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26-28 JUNE 2024, KRAKOW, POLAND

Monitoring transient thermal stresses in pressurised cylindrical components based on temperature measurements

J. Taler[1], D. Taler[1], K. Kaczmarski[1], M. Jaremkiewicz[1], P. Dzierwa[1], M. Trojan[1]

Keywords: transient thermal stresses; inverse heat conduction problem; wall temperature measurement; pressure component; monitoring of thermal stresses,

ABSTRACT

Thermal power plants, both classic and nuclear, must have good flexibility to be able to work in one system with wind and photovoltaic farms [1]. In order to reduce unit start-up and shut-down times and to ensure safe operation during large load changes, it is necessary to monitor the critical pressure components of the unit and to optimise their heating and cooling [1-2]. This paper presents a method for monitoring stresses in pressure components of power boilers. The method can be used to monitor fast start-ups or power changes of the unit to reduce the time of connection of the unit to the electricity grid. By using the developed thermal stress monitoring technique, despite faster start-ups and shut-downs, the life of the power unit is not significantly affected. The circumferential thermal stress at the point of concentration at the opening edge is determined by the stress at a larger distance from the analysed opening. In this case, the hole does not disturb the temperature field in the wall, so the wall temperature only changes along the radius. Then, the transient temperature field in the wall of the pressure element is one-dimensional. The wall temperature of the pressure element is measured at a distance of no more than twelve millimetres from its inner surface. The pressure of the flowing steam inside the element is measured online, too.

The outer surface of the element is thermally insulated, i.e. the heat flux at the outer surface is assumed to be zero. Once the wall temperature field and heat flux have been determined, the inverse heat conduction problem (IHCP) is solved for the area between the measuring point and the inner surface of the element. The circumferential stresses due to pressure and thermal load at the hole edge were determined by multiplying the stresses for the non-weakened wall by the thermal stress concentration factor and the pressure stress concentration factor, respectively. Also, to determine the thermal stress concentration factor, the heat transfer coefficient (HTC) at the inner surface of the pressure component must be known. The HTC is calculated from correlations available in the literature for laminar, transient or turbulent flow. An advantage of the proposed stress monitoring method is that measurement of the steam temperature is not required. Accurate transient steam temperature measurement is difficult due to massive industrial thermometer housings, which greatly attenuate actual steam temperature changes over time. The pressure element's life due to low-cycle thermal fatigue can be determined by monitoring the circumferential stresses at the hole edge.

By monitoring stresses from pressure and thermal loading, the flexibility of the boiler and the entire drive unit can be improved, as heating or cooling of critical pressure components can be accelerated.

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Optimizing Heat Transfer Predictions in Plate Fin and Tube Heat Exchangers Using Artificial Neural Networks

Mateusz Marcinkowski[1]*, Tomasz Cieślik[1], Jacek Sacharczuk[1], Dawid Taler[1], Jan Taler[1]

ABSTRACT

Keywords: Heat transfer prediction, Compact heat exchangers, Artificial Neural Networks, Forecasting, Modelling

Over the last two decades, there has been a significant increase in the use of artificial neural networks in determining optimal operating conditions and predicting heat transfer parameters. Experimental measurements of the operation of the compact (plate fin and tube) heat exchanger were carried out. Heat exchange occurred between hot water flowing inside the tubes and cold air flowing through the fins and tubes. Based on the collected data, such as the inlet and outlet temperature and the water and air flow rate, the air temperature behind the heat exchanger and the temperature of the water leaving the heat exchanger were predicted. For forecasting, an artificial neural network of the Multi-Layer Perceptron (MLP) type with the BFGS (Broyden-Fletcher-Goldfarb-Shanno) learning algorithm with a variable number of neurons in the hidden layer was used. Parameters were predicted for individual random operating points and entire operating ranges. An attempt was made to determine the best neural network models and compare them using the correlation coefficient and the mean absolute percentage error (MAPE) was calculated. The BFGS algorithm, an iterative optimization algorithm, was selected for its effectiveness in solving large-scale optimization problems without the need to compute second-order derivatives.

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Investigation of a two-phase air-water mixture using CFD and radiometric method analysis

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Keywords: CFD, two-phase flow, experimental validation

ABSTRACT

Multiphase flow is common across the industry. In the mining industry, multiphase flow is typically observed as a slurry flow consisting of two or more phases, typically water, ore and air [1]. Power plants utilize steam and water for cooling [2], when distillation columns, reactors, and transport pipelines are the most common places where one can observe multiphase flow in the chemical industry. Its complex phenomena pose a great challenge in the simulation and measurement techniques used to investigate multiphase flow behavior. Understanding its behavior can lead to significant improvements in safety, efficiency, and reduction of greenhouse gas pollution.

Numerical simulation plays a key role in designing new type of multiphase flow measurement equipment. Due to its capability to assess a various number of designs simultaneously, it reduces turnaround times at the development phase. Due to uncertainty of the CFD simulation data, it should always be compared with real-case applications and used for fine-tuning of the models.

One type of equipment used for studies on multiphase flow is radiometric measurement set. These set utilize the Am-241 sealed sources which emits gamma rays, and their intensity is measured by scintillation probes. Knowing that water has higher gamma-ray absorption than air, it is possible to determine void fraction and gaseous strutures in air-water flow. To measure the average velocity of the air, two sets of the gamma sources and scintillation probes are required, because the phase shift between the signals from them is measured to calculate the air velocity (minority phase) [3]. This paper presents simulation techniques used to describe the two-phase flow consisting of an air-water mixture and the potential experimental setup required to validate numerical results.

CFD analysis was used to simulate two-phase flow, using the VOF model. Constant velocities of 1.0 m/s for H_2O and 1.25 m/s for air were applied at the inlet to the channel. The time step size as well as the mesh size were checked, showing a strong influence on the simulation results. Geometry used for simulation is shown in Figure 1. It consists of 30mm of water and 6mm of air inlet, which are mixed downstream.

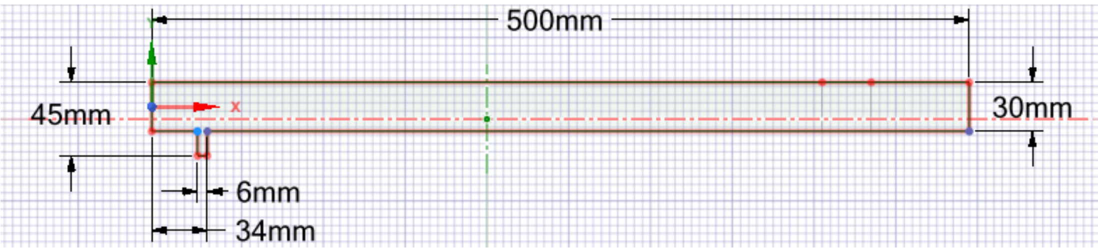

Figure 4. Geometry of the simulated channel

Figure 2. shows comparison of five different mesh densities. They were checked by

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varying the max cell size from 1.0 mm (Mesh 1) to 0.35 mm (Mesh 5), showing that the refinement is necessary. Based on those results, it was decided that variant 4 of numerical mesh, with a max cell size of 0.4 mm will be used for later calculations, as it shows similar results to variant 5 but with lower computational effort.

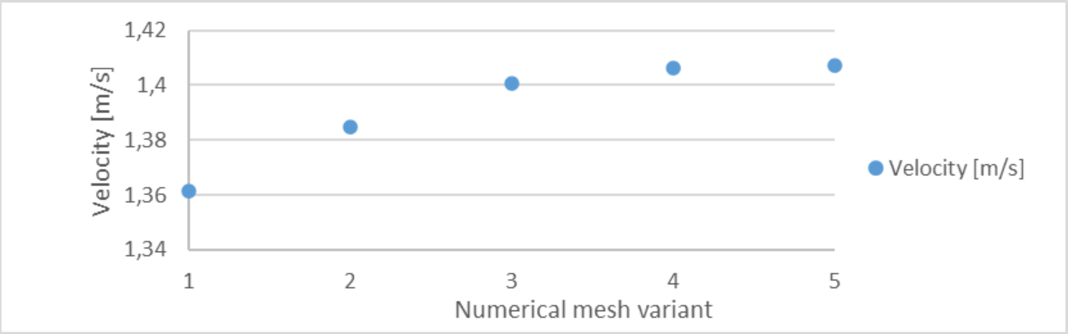

Figure 2. Mesh study results

A constant time step of 0.0001 s was compared to an adaptive one, showing that the average velocity of the mixture differs by up to 0.118%. The mean amount of the water phase changes by 1.959%. This means that the adaptive time step can be used without having a major impact on the quality of the results.

The experimental setup will be based on the gamma-ray absorption technique, used to describe the void fraction and the speed of the mixture. Results from the radiometric instruments will be compared to the ultrasonic flow meter.

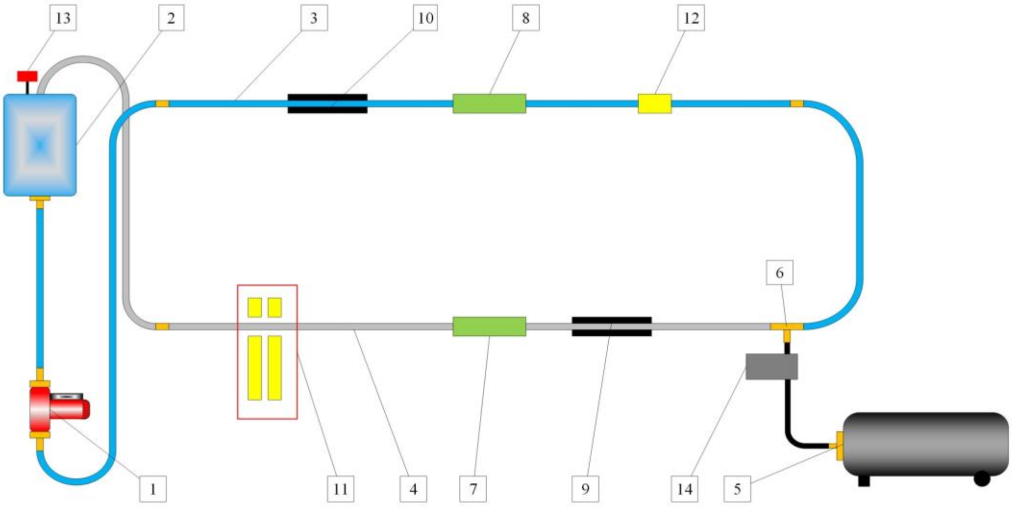

Figure 3. Experimental set-up: 1-pump; 2-gas-removing tank; 3-water line; 4-multiphase flow section; 5-compressor; 6-gas nozzle; 7-orifice (mixture measurement); 8-orifice (water measurement); 9-ultrasound flow meter for a mixture; 10-ultrasound flow meter for a water; 11-radiometric measurement set-up; 12-electromagnetic flow meter; 13-water temperature probe; 14-gas flow meter

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Comparison of nuclear fuel mass balances for small modular reactors and large-scale reactors

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Keywords: mass balance, nuclear fuel, uranium, fuel cycle, SMR.

ABSTRACT

Global trends in nuclear energy show the rapidly ongoing development of SMR (Small Modular Reactor) nuclear reactor technology. SMR reactors are characterized by modular construction and lower power than large-scale reactors, maximally 300 MW_{el} [1]. Therefore, a quantitatively larger number of SMR reactors compared with the large-scale reactors is needed to introduce the same power into the power system.

Every nuclear reactor consumes nuclear fuel in accordance with a previously designed fuel loading and reloading strategy, which is called "in-core fuel management". The number and type of fuel assemblies introduced into the reactor core in each subsequent reactor cycle, as well as their arrangement in the core, depend on the type of nuclear reactor.

In the presented scientific research, a comparative analysis of the nuclear fuel mass balance was performed for the boiling water BWRX-300 SMR reactor and the AP1000 pressurized water reactor [2,3]. The BWRX-300 reactor was chosen because of its close commercialization and market implementation. The AP1000 reactor is already commercially available and operational. Additionally, both types of reactors are light-water reactors, and a simple analysis shows that the nuclear power plant equipped with four BWRX-300 reactors, each with a gross power of 300 MW_{el}, exactly replaces one AP1000 reactor with a gross power of 1200 MW_{el}, which simplifies numerical calculations.

First, the core loading schemes of both reactors were analyzed, taking into account different types of fuel assemblies with different enrichment in the fissile uranium isotope ^{235}U. On this basis, the total mass of fuel needed for the planned designed lifetime of the reactors was calculated. In the next phase, dedicated numerical tools were used to estimate the mass balance for all stages of the front-end nuclear fuel cycle [4], i.e. uranium mining, milling, conversion, enrichment, and fuel fabrication, which gives the mass of the product and waste at each stage [5]. In the last step, a comparative analysis of mass balances for each stage of the front-end nuclear fuel cycle was performed for four BWRX-300 and one AP1000 reactors.

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Energy transformation in Poland – selected systemic, technological and methodological aspects

Bolesław Jankowski[1,*]

Keywords: power system, modelling, renewables, energy storage

ABSTRACT

The dynamic development of RES in Poland in recent years has significantly increased the share of energy produced with zero CO2 emissions, but has also highlighted new problems. One of them is the growing scale of non-market reduction of RES generation by the TSO. Solving this and other problems requires a broader view of issues such as the integration of RES in the National Power System (NPS), harmonization of the development of central sources with the development of local sources, and sectoral integration, especially in the field of district heating and the NPS (including heat storage). Analytical work carried out at National Centre for Energy Analyses (NCAE) addresses these topics from both the substantive and methodological (modelling) perspectives. Selected conclusions from this work are presented below.

Transformation model based on RES and energy storages

Linking RES with energy storage is seen by many as the most favorable pathway for zero-carbon emission transformation. A number of studies have been undertaken at NCAE to verify its feasibility and efficiency. The first stream of work was focused on assessing the maturity and market availability of large-scale energy storage technologies. This assessment indicates that only PHS and lead battery technologies are fully market mature. Large-scale battery storage using lithium-ion cells is in the phase of rapid deployment development, but the experience from their operation is still very modest.

Analysis of the development processes of new technologies shows that after reaching market maturity, new technologies develop according to so-called logistic curve (s-curve), also referred to as a learning curve. The initial phase of development is relatively slow, due to limited production and assembly capacities, limited knowledge of how to integrate these sources into the system, and only later accelerates. This needs to be taken into account when developing an energy transition strategy.

In order to estimate the required scale of energy storage deployment in the "RES plus storage" model, two independent model analyses were performed. Their goal was to quantify the hypothetical state of the NPS using only RES sources and energy storage. In the first case, a dedicated tool developed by the IDEA/NCBJ team optimizing the energy mix over a one-year period was used, while the second used the Plexos model. In the results obtained, the demand for energy storage other than ESP calculated for the 2040 demand forecast was estimated at about 175 GW/720 GWh in the first approach and significantly higher in the second approach.

Analyses of how energy storage facilities are used indicate that this demand is largely driven by the need to cover the large gaps in generation from RES sources that occur throughout the year. For proper operation of the NPS wit RES sources only, sufficiently large storage capacities are needed, which is difficult to achieve with battery storage, and entails very high storage capacity levels, low utilization rates and high costs. Allowing the use of dispatchable sources to supplement RES, such as gas units, drastically reduces the need for battery storage capacity. The results obtained require further verification, deepening and understanding the reasons for obtaining significant differences in results.

Integration of RES with conventional sources

The current level of intermittent RES (about 9.4 GW in wind and about 17.6 GW in PV)

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has already reached the level of peak power demand (about 27 GW) in the Polish NPS. The significant level of non-market RES reductions observed recently indicates the inability to fully integrate these sources into the NPS. This is due to the fact, that generation adequacy is still provided mainly by conventional sources, which have operating constraints (e.g., the minimum level of generation). Analyses performed with various models (TIMES, Plexos) have shown that models that optimize the energy mix over the long term tend to overestimate the optimal RES share, as they work with relatively low temporal resolution and do not fully account for the operation constraints of dispatchable sources. Analyses performed with the Plexos model working in operational (Short Term) mode show that within a defined set of dispatchable units, there is a limited level of RES that can be effectively integrated into the system. Above this level, newly installed RES capacities operate inefficiently, with a very low capacity factor. Increasing RES share requires not so much network investment, but increasing the flexibility of dispatchable sources or the flexibility of demand.

Methodological aspects

The complexity of the transformation processes and the increasing unpredictability of the energy system's operation make the modeling tools used so far and constantly improved not fully adequate for solving transformation problems. In addition to the integration of RES, this also applies to the study of such issues as sector coupling (e.g. district heating) and harmonization of the development of central energy sources with the development of local sources. One can risk the thesis that there is a methodological and modelling gap in this regard. To overcome it, a set of models is being developed at NCAE, which includes the TIMES-PL multi-sector model, the Plexos electricity system optimization model (in Long Term optimization mode), the Plexos working in operational (Short Term) mode, as well as models for local or sectoral development analysis. The design of future energy mix with a high RES share will be developed in an iterative process using soft link between the long term optimization model and the NPS operational model. Sectoral analyses performed with dedicated models will be made consistent by verifying their results within the multi-sector model. Developing a proper set of modeling tools is a serious methodological and practical task, but is necessary to properly design and support energy transformation processes.

From coal & gas company to the supplier of energy transition. E.ON turnaround in Europe and Poland

Wojciech Graczyk[1]

ABSTRACT

E.ON is a European energy company with German origins that made a significant from the coal and gas exploring / electricity generation and supply of electricity and gas company into the supplier of energy transition being concentrated on renewables, network operations, sales business and supplier of integrated energy solutions for customers. The way E.ON changed into what is today is an example of structural and organizational developments on the European and Polish energy markets and reaction to different constraints a modern energy company must mitigate, including the financial ones. The E.ON way could also be treated as an reference for any other vertically integrated energy company with conventional production of electricity.

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[1] E.ON Polska S.A.

Hydrogen compressors for vehicle hydrogen refueling stations - SERA and Hennlich experience

Rafał Iwaniak[1],*, Tim Lorenz[2]

Keywords: Refuelling stations, compressors, KOH pumps, hydrogen nozzles

ABSTRACT

The **sera Hydrogen GmbH** has been offering solutions for the high-purity compression of gases for over 70 years. Due to the clean compression, the technology of metal diaphragm compressors has been used in the technical gases, semiconductor and process gas industries for decades. In addition to these classic industrial applications, around 50% of the compressors supplied today are used for hydrogen applications in the renewable energy sector. The diaphragm compressors can be designed as a single unit, as an automated system or as a complete containerized solution. These containerized solutions are used particularly in the field of power-to-gas systems, as they are available as plug-and-play solutions. In addition to the diaphragm compressors, sera Hydrogen GmbH also has small piston compressors in its portfolio, which are in series production and are therefore characterized by low costs and short delivery times. These compressors are also available as individual units or as complete systems and are used in the home power sector. To complement the portfolio, sera Hydrogen GmbH can offer complete hydrogen refuelling systems for smaller fleets.

Figure 1. Complete hydrogen refueling solutions

Sera supports the customer right from the engineering phase and accompanies him competently through to project realization. With its own trained personnel, sera takes over the service, commissioning and installation of the system worldwide. Alternatively, training courses can be offered to enable the customer to carry out maintenance independently.

In order to provide customers in the respective countries with optimum support, sera has maintained good relationships with partners in various countries for decades.

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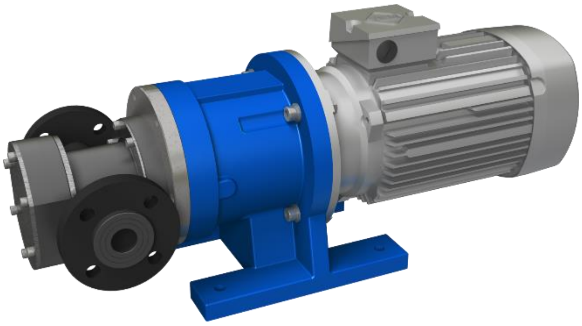
Our partner **Hennlich sp. z o. o** in Poland, the Czech Republic and Slovakia is a company that is able to optimally support and advise customers in the design and supply industry in the field of complete hydrogen refueling solutions for cars, buses and trains.

For tank hydrogen vehicle **Hennlich sp. z o. o**. as the exclusive, certified representative of the manufacturer WALTHER-PRÄZISION, is a distributor of the HG series high-pressure refuelling system – Figure 2. It was developed for safe and quick refuelling of hydrogen gas. A typical application is the refuelling of fuel cell vehicles to an operating pressure of 350 / 700 bar. Refuelling nozzles are tested and approved in accordance with SAE J2600 and ISO 17268, global fuelling standards. For refuelling vehicles with high-pressure hydrogen gas, WALTHER-PRÄZISION offers a specially designed refuelling system. The main components of this system are the breakaway coupling, the hose kit, the refuelling nozzle and the parking station.

walther präzision
WalCoDo®
WALTHER CONNECTING & DOCKING

Figure 2. WALTHER-PRÄZISION hydrogen quick couplings refueling nozzles.

In addition to sera compressor and hydrogen technology we will also present Pump ready for the next generation electrolysers Figure 3



MARCH PUMPEN
...ADVANCED SOLUTIONS...

Figure 3. MARCH magnetic gear pump TEF-MAG® for alkaline electrolysis.

On Figure 3. TEF-MAG® PEEK gear pump from **MARCH PUMPEN** made for various applications with 30% potassium hydroxide at operating temperatures of up to 90°C, such as alkaline electrolysis, the MARCH magnetic gear pump TEF-MAG® was designed and manufactured of high-performance plastic PEEK (polyetheretherketone) specifically according to user requirements. Using non-metallic materials for potassium hydroxide (KOH) electrolysis has several advantages. Firstly, metallic materials can corrode and wear out at high temperatures and high concentrations of caustic potash, which can lead to failures and inefficiency. The use of non-metallic materials, especially plastics, can solve this problem as they are usually more chemically resistant to KOH and other electrolyte solutions. Secondly, the use of non-metallic materials can reduce the risk of contamination from metal ions that may be released into the electrolyte solution and interfere with the electrochemical reactions or produce undesirable by-products.

Hennlich sp. z o. o. is a company that has been introducing world-class solutions in the field of hydrogen technologies for years, which will be presented at the conference.

Positive effect of high - temperature hydrogen treatment in titanium alloy

Maria Sozańska[1]

Abstract

Positive nature of the effects of hydrogen on the properties of titanium alloys is manifested in the high temperature hydrogen treatment (*HTM - Hydrogen Treatment of Materials*), where hydrogen is temporary alloying component. This is possible because of the high values of diffusion coefficients can be easily introduced into the titanium and it just as easily removed. The hydrogen in titanium alloy is present in the form – an interstitial solution or titanium hydride. Since the specific volume of titanium hydride is about 13 ÷ 17% higher compared to α phase, it is high stress in the crystal lattice of this phase leads to local plastic deformation and large deformation phase.

The aim of this study is thus to determine the effect of hydrogen on the two-phase microstructure, mechanical properties, and surface fracture of the titanium alloy Ti-6Al-4V due to HTM, especially high-temperature cyclic hydrogen treatment with glow discharge. Research on the effects of hydrogen on the microstructure of the titanium alloy Ti-6Al-4V showed that the processes causing the high-temperature hydrogen treatment of grain refinement and alloy plate structure occur in a 50 μm surface layer. High-temperature cyclic hydrogen treatment is a very powerful method to modify the microstructure and mechanical properties of two-phase titanium alloys.

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Hydrogen used as fuel for combustion engines

Marek Brzeżański[1], **Michał Mareczek**

Abstract

Since the 1980s, scientific research has been conducted at the Cracow University of Technology using hydrogen as a fuel for piston combustion engines. In the years 2012 to 2018, a research project was carried out involving the use of waste hydrogen from industrial installations to power power generators. Because the hydrogen used in this project was contaminated with other components, mainly nitrogen, carbon dioxide and hydrocarbons, an innovative control system was developed that allows automatic adjustment of the engine regulation parameters to the current chemical composition of the offered fuel. This regulation method was applied to three piston combustion engines powered by waste hydrogen, with a total power of approximately 1 MW. Operational tests of these engines were carried out over a period of 5 years.

Thanks to the experience gained in this project, since 2020, a project to adapt a modern industrial engine to be powered by pure hydrogen or hydrogen-natural gas mixtures has been implemented at the Cracow University of Technology. For this purpose, a system for burning this type of fuel and a modern power supply system operating in adaptive mode were developed. In addition, new safety systems for powering piston combustion engines have been used, protecting the system against flame flashback. Preliminary results indicate a high implementation potential of the project.

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The role of the mineral industry in the energy transition and green hydrogen energy economy

Adam Smoliński[1,*]

Keywords: green hydrogen, gasification/co-gasification, electrolysis, critical minerals, energy storage

ABSTRACT

The development of the hydrogen economy has become a driving force of the energy transition towards sustainable energy solutions [1-4]. The Polish Hydrogen Strategy and the Sectoral Agreement for the Development of the Hydrogen Economy in Poland provide a roadmap for the development of the hydrogen economy in Poland [1]. In fact, these documents outline a comprehensive roadmap for using hydrogen as a key enabler of decarbonization and energy transition. With ambitious targets for scaling up hydrogen production, infrastructure and use, the strategy emphasizes the importance of green hydrogen from renewable sources to reduce carbon emissions and increase energy security [5-8]. By promoting investments in electrolysis facilities, hydrogen storage and distribution networks, Poland aims to establish a robust hydrogen value chain supporting various sectors, including transport, industry and heating.

One of the crucial element of the energy transition is the demand for critical minerals. Critical minerals play a vital role in the energy transition by enabling the production of key technologies such as rechargeable batteries, photovoltaic panels, and wind turbines. Elements such as lithium, cobalt and rare earth metals, are essential to advancing renewable energy sources and reducing dependence on fossil fuels. However, their limited supply chain, geopolitical implications, and environmental concerns pose challenges to the sustainable development of clean energy technologies. Balancing the need for critical minerals with responsible sourcing practices and recycling efforts is critical to ensuring a successful energy transition to a more sustainable future.

Green hydrogen is key to the energy transition to a zero-emission future [8-12]. The paper will also present case studies of green hydrogen production. These will focus on the combination of electrolysis with photovoltaic farms and the gasification of biowaste and sewage sludge. Both options are effective ways to produce hydrogen without harming the environment. The combination of electrolysis and solar power offers a way to produce green hydrogen in large quantities while reducing our dependence on fossil fuels. Furthermore, an experimental study on the gasification and co-gasification of biowaste and sewage sludge is presented. The gasification/co-gasification of biowaste/sewage sludge provides additional opportunities for green hydrogen production. Converting organic waste materials in the gasification process into syngas and further separating hydrogen makes it possible to valorize waste streams while producing green hydrogen. The co-gasification of different feedstocks, such as biowaste and sewage sludge, enhances the efficiency and flexibility of hydrogen production processes.

In conclusion, the production of green hydrogen through multiple pathways, including electrolysis combined with photovoltaic farms and gasification of organic waste, represents a compelling strategy to drive the energy transition towards the Green Deal's primary goal of climate neutrality by 2050.

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Adsorption of emerging contaminants onto modified and unmodified microplastic

Laura Frydel[1],*, Jagoda Worek[1], Katarzyna Berent[1], Daniel Kaleta[1], Katarzyna Styszko[1]

Keywords: microplastic, adsorption, emerging contaminants

ABSTRACT

Emerging contaminants are a group of compounds that includes wide range of different emerging contaminants, such as: pharmaceuticals, personal care products, endocrine disrupting compounds and polycyclic aromatic hydrocarbons [1,2]. Compounds belonging to the group of "emerging contaminants" are trace organic pollutants with unregulated concentration levels safe for organisms and the environment. As analytical techniques develop, they are increasingly detected in the natural environment. Their main source is industry, municipal (domestic), agricultural, hospital or laboratory sewage. Pharmaceuticals and endocrine disrupting compounds raise a significant concern, due to its wide usage and huge impact on organisms. These groups include antibiotics, analgesics, steroids, painkillers and betablockers [1]. Another group of compounds that continuously enter the environment and is frequently detected in diverse environmental samples is polycyclic aromatic hydrocarbons (PAHs) and their derivatives [2]. PAHs are formatted through pyrolysis and incomplete combustion of organic matter. Polycyclic aromatic hydrocarbon pollution may be of natural (forest fires, volcanic eruptions) or anthropogenic (incomplete combustion of wood, fossil fuels, vehicles) origin [3]. The properties of PAHs that influence the fate of these compounds and their resistance in the environment are: hydrophobicity, thermostability, and aromatic ring structure. PAHs are of emerged concern due to their mutagenic, cancerogenic, highly toxic, immunotoxicogenic and teratogenic properties [4]. One of the most known group of derivatives of polycyclic aromatic hydrocarbons are hydroxy derivatives. They are generated through metabolization of polycyclic aromatic hydrocarbons that take place in organisms. Hydroxy derivatives of polycyclic aromatic hydrocarbons (OH-PAHs) are biomarkers of human exposure of PAHs [5,6].

Microplastics are fragments of plastic pieces, which formed different shapes. The size of these particles ranges from 100 nm to 5 mm in diameter [7]. The production of origin plastic has increased throughout the years and reached last year 359 million tons per year [8]. Study shows that microplastics is detected starting in freshwater and seawater, sediments, air and ending in organisms, also in humans [9]. There are two types of microplastics pollution: primary microplastics, which is microplastics that were generated already as microplastics size range and secondary microplastics, which originally was plastics in macro size and were fragmentated by weathering [8]. The negative influence of microplastics on flora, fauna and humans are well documented. Studies did not provide definite conclusions about harmful impact of microplastics on human's health, but they may impact on endocrine system of human, physically stimulate the human body and cause ecotoxicology [8,10,11].

The structure of microplastics is unique. Microplastics consist of carbon chains and benzene rings and high number of functional groups, therefore they are capable of bonding different kind of contaminants through van der Waals forces and hydrogen bonds [8]. Due to the large specific surface area and strong hydrophobicity, microplastics can be used as adsorbents of micropollutants [12]. Although microplastics and micropollutants are consider toxic to the environment, adsorbing pollutants onto the surface of microplastics

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allow to achieve simultaneous removal of microplastics and micropollutants [10]. Moreover, the carbon structure present in the microplastics is stable and easy to separate. Due to that they are potentially effective adsorbent for sewage treatment plants [10].

The aim of this study was to use microplastics before and after the aging process as adsorbent of hydroxy derivatives of polycyclic aromatic hydrocarbons. The aging process consisted of different time exposure to ultraviolet radiation (UV A/B) and added 30% hydrogen peroxide solution.

The SEM images of microplastics were taken using a dual-beam focused ion beam/scanning electron microscope (FIB-SEM). Fourier transform infrared (FTIR) spectroscopy was used to record IR transmittance spectra of MPs and to identify functional groups specific to them. For these purposes, a PerkinElmer Frontier Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR FTIR) spectrometer was applied with the MIR range and DTGS detector and an additional wide-range MCT detector. The FTIR spectra were measured in the wavenumber range of 530-4000 cm^{-1} and averaged 64 scans per spectrum at room temperature. The concentration of hydroxy derivatives of polycyclic aromatic hydrocarbons was determined using Thermo Scientific Liquid Chromatography with tandem mass spectrometry (LC-MS/MS). The tested compounds used in adsorption studies were OH-PAHs. The contact time of adsorbent and adsorbate was: 30 min, 1h, 2h, 3h, 4h, 5h, 18h, 24h and 1 week. The concentration of OH-PAHs was: 1, 2.5, 5, 8, 10 and 20 ng/ml.

Figure 1 presents the variable microstructure of microplastics. Some of it was smooth with numerous cracks and defects, and some were intensely porous. In each case, the separated microplastic had adsorption potential. The FTIR spectra showed the intensive band at 1730 cm^{-1} assigned to C-O stretching vibration of carbonyl groups [13]. Adsorption studies showed removal of hydroxy derivatives of polycylic aromatic hydrocarbons by microplastics before and after aging process, confirming good adorptive properties of microplastics.

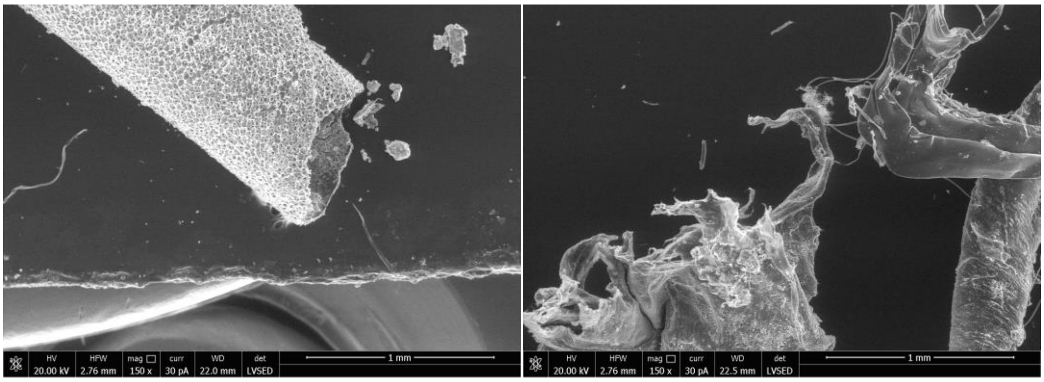

Fig. 1. SEM images of microplastics.

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Hydrogen as a zero-emission fuel – an opportunity for energy-intensive industries

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Keywords: hydrogen, zero-emission, industry

ABSTRACT

Hydrogen is seen as the possible fuel of the future. Hydrogen fuel is considered emission-free because, during combustion, the only main by-products are water (water vapour) and trace amounts of nitrogen oxides, which are much smaller than the amounts produced by the combustion of conventional fuels. Hence, hydrogen can be an alternative to fossil fuels due to its chemical and physical properties.

The European Green Deal is a European Union economic development strategy whose goal is a deep pro-ecological reconstruction of the European Union economy. The use of hydrogen as an alternative fuel fits perfectly into this strategy. Replacing conventional fuels with hydrogen-enriched or, ultimately, pure hydrogen fuels will mainly concern industries that are based on high-temperature (and therefore energy-intensive) processes. These include, among others, the industrial energy, steel, metallurgy, foundry, cement, and coke industries, as well as the production of glass and ceramic products and building materials, including modular construction and refractory.

Therefore, it is extremely important to answer the questions of whether and how the use of hydrogen as a fuel will affect technological processes (including manufactured products and materials), what consequences the use of hydrogen fuel will have in existing installations, devices, and technologies used, and whether and what modifications will be necessary to introduce hydrogen as a zero-emission fuel. Testing the use of hydrogen fuel in currently operating industrial installations involves the risk of reducing or stopping production, making it necessary to provide entrepreneurs with the opportunity to test hydrogen fuel in a research installation on a quarter-technical scale. Previous experiences to be presented will illustrate the impact of hydrogen on ceramic linings depending on the temperature and operating time of the installation. Examples of ceramic corrosion will be presented, and the risk of using hydrogen fuel without previously conducted tests on a semi-technical scale will be discussed.

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Energy efficiency and economy analysis of an extended range unit involving a polymer exchange membrane fuel cell stack

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Keywords: fuel cell stack, energy efficiency, hydrogen, extended range unit

ABSTRACT

This paper presents the results of numerical and experimental investigations on an advanced model of a polymer exchange membrane fuel cell (PEMFC) stack designed to serve as a charging unit for electric vehicle batteries or off-grid decentralised power sources. A scalable, modular PEMFC stack in the 1-5 kW range was selected for the investigations. The designed and assembled 720 W PEMFC stack consisted of two 360 W modules that can be connected electrically in series or in parallel. A liquid cooling system for the PEMFC stack was also designed. The dependencies – voltage (U) versus current (I) and current (I) versus electrical power (P) – for individual modules and for the electrically connected PEMFC stack with two modules were determined. In addition, hydrogen utilisation was investigated as a function of the electrical power of the PEMFC stack. The electrical efficiency of the PEMFC stack varied between 42% and 50%, depending on the electrical power. An adjustable DC/DC converter, operating in two modes (buck or boost), is proposed as an integration unit for the battery and the PEMFC stack. The electrical architecture of the integrated system, consisting of the PEMFC stack, the DC/DC converter and the Li-ion battery pack, is analysed and discussed in this paper. It was found that the electrical efficiency of the proposed DC/DC converter varies depending on the electrical power, reaching a peak efficiency of 95%–98%. Durability, lifetime and economic analyses are also discussed. The specific application of such devices in electric drive units as well as in off-grid power supply systems is proposed. The analysis of the elaboration of a scalable fuel cell unit for range extension is also proposed for various specific areas.

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Plans and assumptions for the implementation of hydrogen buses at MPK S.A. in Kraków

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Keywords: Hydrogen, Hydrogen bus, Hydrogen infrastructure, Hydrogen transport,

ABSTRACT

Hydrogen buses are an innovative solution in public transport that contributes to reducing emissions of harmful substances into the atmosphere and increasing energy efficiency. The article discusses the advantages of using hydrogen-powered buses, such as low CO_2 emissions and other pollutants, quiet engine operation and fast vehicle charging. In addition, the results are presented.

Hydrogen buses are becoming more and more popular buses for public transport. Their development can contribute to more efficient and ecological public transport. This is a great opportunity to move away from fossil fuels and conventional drives towards sustainable transport.

The aim of the article is to present the current experience of operating hydrogen buses and development plans for hydrogen infrastructure in MPK Kraków. MPK has tested three 12-meter Solaris buses, Arthur Bus i Autosan and one 18-meter Solaris U18, all with hydrogen drive. The premiere of an 18-meter hydrogen bus by Mercedes-Benz also took place in Krakow. Currently, Solaris Urbino 12 is undergoing long-term tests in Krakow and operates in urban traffic with passengers on a fixed line. The article will present experiences with operating buses, but also legal and technical problems in operating them. Currently, MPK plans to adapt one station to service and park hydrogen buses. There are also plans of KHK (Krakowski Holding Komunalny) to produce hydrogen using electrolyzers on the premises of MPK. The presentation presented basic technical data of the tested hydrogen buses. MPK's plans to develop towards hydrogen drives were discussed. The authors also focus on the infrastructure necessary for the operation of hydrogen buses, such as hydrogen refueling stations and the logistics network supporting the operation of these vehicles. The article also highlights the challenges associated with introducing hydrogen buses in the transport market, such as high production costs and limited availability of hydrogen refueling. Ultimately, the authors suggest that hydrogen buses have the potential to become a significant element of the strategy to reduce pollutant emissions in public transport, but further support from institutions and the automotive industry is necessary.

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[1] Miejskie Przedsiębiorstwo Komunikacyjne S.A. w Krakowie

ENERGY FUELS ENVIRONMENT EFE2024
26-28 JUNE 2024, KRAKOW, POLAND

Building nuclear workforce for a newcomer country

Paweł Gajda[1],*, Jadwiga Najder[2]

Keywords: nuclear, education, training, human resources

ABSTRACT

Poland, having its established nuclear research tradition and infrastructure and an experience of unsuccessful attempt on a NPP construction, now again is a newcomer country with a nuclear power program ongoing. Similarly to global counterparts, Poland faces workforce challenges, among others a pronounced generational gap within the professional community.

Addressing the workforce challenges requires a systemic approach to Human Resource Development (HRD) and Nuclear Knowledge Management (NKM), recognizing the interdisciplinary nature of the nuclear sector. Important part is to be played by academia, with only a handful of academic institutions having necessary expertise in some areas at present moment. This entails crafting a comprehensive training framework spanning secondary education, universities, scientific research, and specialized industry training. In order to provide both 'know-how' and 'know-why', the implementation of tailored research programs is essential. Moreover, well-focused efforts are needed to attract and retain young talent in nuclear, in particular protecting education and research fields from workforce drain to other professions and sectors. Several proposed actions leading to creation of a comprehensive education system will be presented.

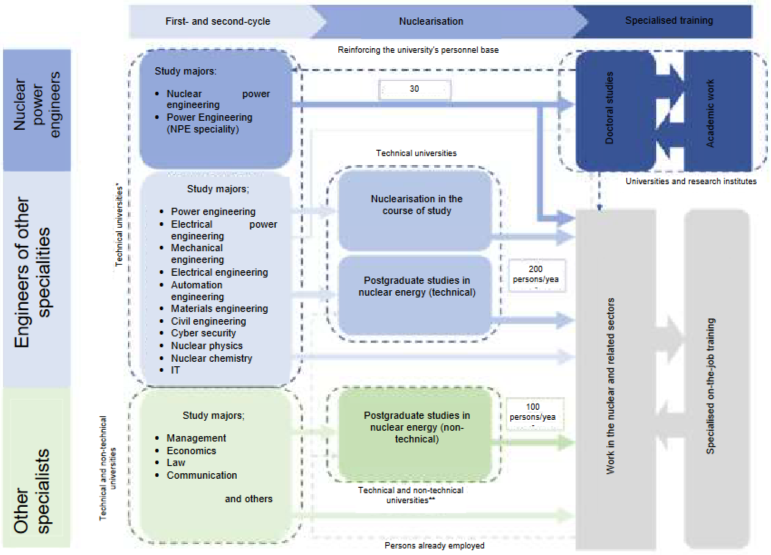

Figure 1. Education and training system at the profesional level [1]

[1] Human Resources Development Plan For The Nuclear Power Industry, Ministry of Climate and Environment, Warszawa (2023)

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Biohydrogen and alternative fuels for solid oxide fuel cells

Bartosz Adamczyk[1], Magdalena Dudek[1*], Hassan Ali[2], Tatiana Maslak[3], Anita Zych[1]

Keywords: Biohydrogen, SOFC, biomass, waste, circular economy

ABSTRACT

Climate change is one of the greatest challenges for both the current and the future world. To mitigate this process, many countries around the globe are undergoing energy transitions to a circular economy (CE) model and low- or non-emission power sources. Emphasis is primarily being placed on the introduction of renewable energy sources, nuclear energy, utilisation of waste biomass and hydrogen economy. Hydrogen, especially green hydrogen, is a highly promising energy carrier that has the potential to decarbonise transportation.

However, hydrogen production is currently dominated by processes using fossil fuels, while green hydrogen processes are underrepresented. As such, it is necessary to research and identify additional viable and climate-friendly methods of hydrogen production. Some compelling alternatives are those that utilise renewable resources that are abundant and widely available. Waste materials, such as biomass obtained from agriculture, animal husbandry, food industry or municipal wastewaters, are a perfect candidate. There are several methods for turning such material into hydrogen-rich gas. One such method is biomass gasification, which creates syngas ($CO + H_2$) as its main product; another is the biotechnological method, which incorporates hydrogen-producing microorganisms that create hydrogen as a byproduct of consuming waste biomass.

Biotechnological methods also provide many other configurations and solutions. Some are based on dark fermentation, some on photo-fermentation and others on direct biophotolysis. One highly promising solution is dark fermentation because its setup is extremely similar to one used in biogas production and does not require access to sunlight. The primary advantage of biotechnological methods is the mild conditions in which the process takes place – there is no need to use high pressures and temperatures, which are required for gasification. The main drawbacks are the slow rate of production, a dependence on substrate composition and the effort required to prevent the bioreactor fom being contaminated by other microbial cultures.

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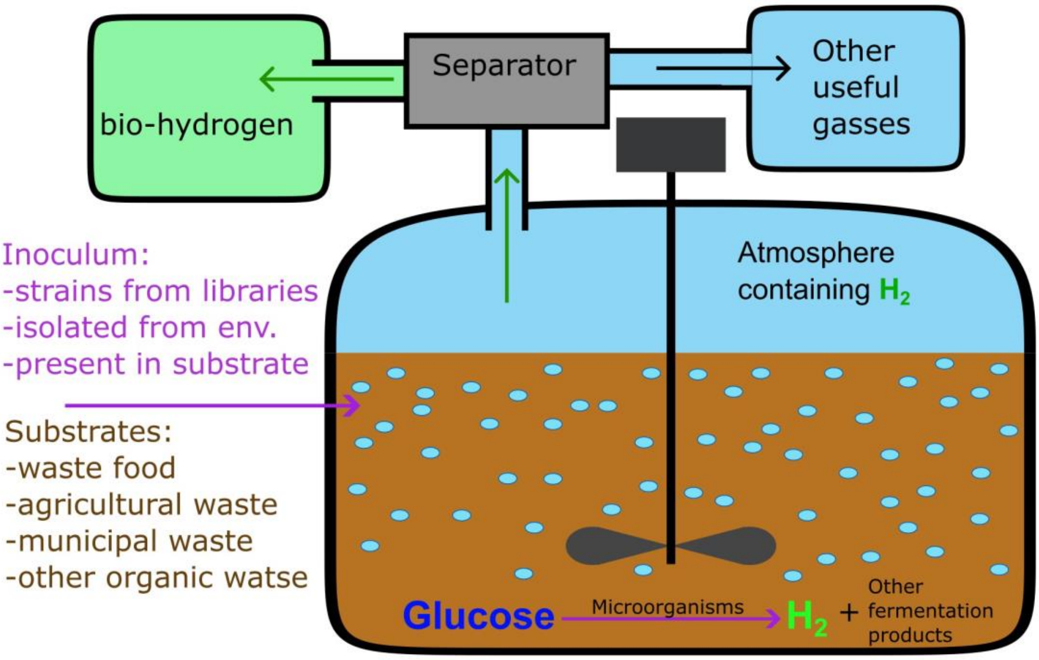

Figure 1. Biohydrogen plant scheme.

Nevertheless, biohydrogen, or hydrogen obtained from biomass gasification, can be utilised to fuel solid oxide fuel cells (SOFCs), which are electrochemical devices that convert the chemical energy of fuel directly into electrical energy. These cells offer superior energy efficiency compared to traditional combustion engines, gas turbines, etc. Moreover, SOFCs can be fuelled indirectly by biomass via gasification or biohydrogen pathways, or directly by delivering waste biomass into anode chamber of the SOFC. Both solutions have their advantages and disadvantages, and the best solution depends on the type of biomass.

Both methods used to convert waste biomass into energy fit the CE model, allowing waste resources to be recycled for materials or energy.

ENERGY FUELS ENVIRONMENT EFE2024
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The multi-criteria method of investing effectiveness evaluation for modern energy supply systems sustainable development modelling

Waldemar Kamrat[1,*]

Keywords: Decision making, Effectiveness evaluation, Modelling investment process, Multi-criteria method, Sustainable energy supply systems development

ABSTRACT

A solution to the decision-making problems towards to sustainable modern energy sector, and in particular the evaluation of investment effectiveness, are closely regarded to modeling, which relatively accurately reflects the complexity of market economy mechanisms. The important problem in the processes of modeling and programming the development of sustainable energy sector is the multi-criteria manner of assessing the effectiveness of investments. The goal of this paper is to show how to take into account the impact of investments in multidimensional modeling decision-making processes. This goal can be achieved through the development, presentation, and use of a new multi-criteria method of evaluating the effectiveness of investing towards to modern energy sector. This innovative method was developed and tested in research for the energy sector carried out by the author. It is a new multi-criteria method, consisting of a relatively simple way of taking into account the qualitative features of the criteria in the process of evaluating investments in the energy sector. Using the real data of the energy invested in the city of X in Poland, the effectiveness of the project was examined applying the multi-criteria method proposed by the author, and for the same purpose, the well-known ELECTRE method was used. The comparison of the results of the investment effectiveness studies by both methods confirmed the high convergence of the effects obtained in both methods. The achieved results of research very high effectiveness of the analyzed renewable energy technologies were proved.

The applied calculation procedures, using identical assumptions and initial databases according to the author’s method (W-1) and the ELECTRE method (W-2), allowed comparing the studied investment options and ranking them from the best to the worst.

Both multi-criteria methods principally stem from different positions, namely:

- W-1 method strives to establish the order of studied investment options on the basis of partial criteria decomposition, followed by a synthesis of partial evaluations, leading to assigning an evaluation measure fi,
- W-2 method establishes the order of studied options without defining a quantity evaluation measure of particular strategies.

The proposed multi-criteria method analyzed in relation to possible investment strategies shows high modernization effectiveness on the supply side (mainly the modernization of transmission systems, distribution, automation of networks and heat distribution centers, application of modern technologies and high-performance power equipment), and on the demand side (thermo - modernization of houses, modernization of recipient installations, application of DSM rules). The high effectiveness of demand options in the investigated case study results also from the fact that the ventures, thermo - modernization, in particular, concern housing districts that were built several years ago using energy-consuming technologies. Lowering energy consumption in houses will require big financial means. On the other hand, ventures on the demand side face the dispersion of financial assets due to the number of recipients being higher than the number of energy

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producers and distributors.

It is very often the cause of decision-making and project coordination problems connected with potentially highly effective investment options. Apart from high effectiveness on the supply-demand side, considerable profitability is characteristic for combined systems strategies, utilizing biomass, or natural gas. Their effectiveness will increase even more in the case of an increase in relatively low prices of electricity. It concerns also non-conventional energy supplying systems such as heat pumps or fuel cells, which have already shown high effectiveness. If various partial criteria are taken into account, investment in traditional coal energy systems has proven to be the least effective.

As the author's studies infer the introduced scientific method can be a good tool to support decision modeling and enables taking rational decisions concerning investment towards sustainable renewable energy in power engineering.

Utilization of Waste Heat in the Thermal Treatment of Sewage Sludge

Tadeusz Żaba[1,2]*

Keywords: wastewater, sewage sludge, utilization, biogas (max. 5)

ABSTRACT

Water supply and sewage disposal are one of the main elements of the proper functioning of the city. Wastewater is sent via the sewage system to a sewage treatment plant, where it undergoes a purification process that consists of two main technological processes. These are mechanical and biological wastewater treatment processes. After a complicated technological process, the treated sewage is directed to the receiver, and the residue from the treatment process is municipal sewage sludge. On average, Krakow's sewage treatment plants produce approximately 260 tons of sludge per day, dewatered to approximately 24% dry matter. Calculated on dry weight, this amounts to approximately 64 tons. Approximately 20,000 tonnes of dry matter of sludge remains to be managed annually. The applicable regulations do not allow it to be stored, and the maximum period of its stay at the place of production cannot be longer than one year. Therefore, the sediment requires further management. The best solution for its management is thermal disposal while maintaining all environmental protection requirements. In order for sludge to be subjected to thermal utilization, it must meet certain conditions. The dry matter content of the dewatered sludge must be between 26 and 22 percent. At the Krakow Thermal Sludge Utilization Station, sludge is subjected to a thermal utilization process using the fluidization phenomenon. The advantage of such a process is the uniform distribution of the entire stream of supplied air over the cross-sectional surface of the reactor, good mixing conditions in the sand layer and ensuring optimal contact between the combusted waste and the supplied air. During the process, heat is generated, which is used to heat the fluidization air introduced into the air chamber and generate steam to power the steam dryer used to dry the sludge to a content of approximately 34% dry matter. Waste heat is used to heat technological facilities at the treatment plant. The scope of the report will include the process of recovery and utilization of waste heat for heating wastewater treatment plant facilities.

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Advances in solar thermal power and chemistry

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Keywords: Concentrated solar thermal, high temperature, thermochemistry

ABSTRACT

High-flux solar irradiation obtained with optical concentrators is a viable source of clean process heat for high-temperature physical and chemical processing [1]. Traditionally, the progress in concentrating solar thermal technologies has been driven by advancements in concentrated solar power, in particular in the context of large-scale dispatchable power generation [2]. Solar thermochemistry is concerned with direct thermochemical production of chemical fuels and materials processing, without intermediate electricity generation, promising high energy conversion efficiency [3]. In this presentation, the potential of high-temperature solar thermal technologies is discussed in the context of coupling rich solar resources of the global sunbelt with the global efforts to transition to a carbon-neutral economy. Scientific and technological advances in solar thermal power and chemistry are ellucidated with examples of selected experimental and numerical studies of concentrating solar collectors, solar thermochemical reactors and redox materials for production of solar fuels and for thermochemical energy storage.

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ENERGY FUELS ENVIRONMENT EFE2024
26-28 JUNE 2024, KRAKOW, POLAND

Legal Conditions for the Storage of Radioactive Waste and Spent Nuclear Fuel in the Light of the European Renaissance of Nuclear Energy. Comparative Approach: Poland, EU, World

Kamil Zawicki[1]

Keywords: radioactive waste; spent nuclear fuel; nuclear law; nuclear energy

ABSTRACT

Introduction:

Radioactive waste management is an integral part of the peaceful use of nuclear energy. In view of the planned construction of at least one nuclear power plant, Poland is facing new challenges in this respect, and these plans must be accompanied by a coherent approach to radioactive waste management. This presentation will discuss the legal framework for the management of radioactive waste, which can be divided into two categories: low and intermediate level waste and high level waste (including spent nuclear fuel). The basic framework for radioactive waste management in Poland is the Act of 29 November 2000. - Atomic Energy Act (i.e. Journal of Laws 2023, item 1173, 1890), the National Plan for the Management of Radioactive Waste and Spent Nuclear Fuel and the Polish Nuclear Power Programme.

Low and intermediate level waste - a Polish perspective, *de lege lata* and *de lege ferenda:*

The regulatory environment and the solutions implemented in Poland, their practical functioning and assessment, such as the Radioactive Waste Neutralisation Facility ("ZUOP") and the National Radioactive Waste Repository ("KSOP"), will be discussed first. These are institutions that have been operating in Poland for many years, but the construction of at least one nuclear power plant in Poland in the next decade poses new challenges in terms of increasing the amount of low and intermediate level waste.

In accordance with the National Plan for Management of Radioactive Waste and Spent Nuclear Fuel, the construction of a New Radioactive Waste Repository ("NSOP") is planned. The operation of the repository is expected to start around 2032, however, the location of this undertaking has not yet been selected, although the National Plan assumed that the selection would be made in 2022. This has not yet happened, and the deadline for municipalities to submit their applications is to be extended again. The reasons for the lack of a location selection can be attributed to existing regulatory barriers and the lack of adequate incentives, particularly in the wording of Article 57(1) of the Atomic Law concerning financial benefits for the municipality in which the repository is located. In this regard, there is room for changes to the regulations.

Spent Nuclear Fuel - A Comparative Polish Perspective:

Surface repositories are not suitable for the storage of high-level waste, including spent fuel. From the point of view of the legal environment, the spent fuel management models used are important. A distinction can be made between an open loop and a closed loop. An open cycle is based on the fact that spent fuel is stored directly. A closed cycle, on the other hand, is based on the diversion of spent fuel for recycling.

Countries that do not use the closed cycle usually have their own repositories, although the practice of sending spent fuel back to the country of origin does occur. In contrast, countries that have opted for the closed cycle (recycling) and do not have their own recycling facilities send spent fuel to other countries. Currently, spent fuel is stored in a variety of ways: in water pools next to the reactor (initial storage phase for the first years after use to reduce radioactivity), in dry storage or in underground tanks. However,

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these methods are considered to be temporary. Ultimately, the Deep Geological Repository (DGR) method is considered to be the safest. At present, such a method is not yet in practice and the closest to establishing it is Finland, which plans to hand over such a repository as early as 2025. In countries that do not use a closed cycle, the issues of central repository, local dispersed storage, steps towards the creation of a DGR are open and problematic.

As far as the situation in Poland is concerned, a similar framework for dealing with spent nuclear fuel is found in the Atomic Energy Act, the National Plan for Radioactive Waste and Spent Fuel Management and the Polish Nuclear Power Programme. The presentation will discuss the basic legal provisions, the role of ZUOP, the schedule of planned activities, the issue of the European Storage Development Organisation and plans for the construction of a Polish deep geological repository for radioactive waste, the hypothetical issue of recycling and a possible update of the Polish Nuclear Power Programme.

Summary:

Poland needs to solve urgent problems related to radioactive waste management in order to safely develop its nuclear power programme. The selection of the NSOP site and the possible construction of the deep repository are key challenges in this area. In order to address them effectively, legislative intervention and a possible update of strategic documents should be considered.

Biofuel and Hydrogen as an Sustainable Alternative Fuel for IC Engine

Sushant Satputaley[1,*]

Keywords: Biofuel, Hydrogen, Alternative fuel, IC Engine

ABSTRACT

As the world seeks cleaner and greener energy solutions, biofuel and hydrogen options have gained considerable attention due to their potential to reduce carbon emissions and dependence on fossil fuels. In this presentation, the detail study of the properties, benefits, and challenges associated with biodiesel and hydrogen, highlighting their role in promoting a sustainable future for IC Engine.

The indian biofuel Policy aims at main streaming of biofuels in the energy and transportation sectors of the country in coming decades. The Policy will bring about accelerated development and promotion of the cultivation, production and use of biofuels to increasingly substitute petrol and diesel for transport and be used in stationary and other applications. The Goal of the Policy is to ensure that a minimum level of biofuels become readily available in the market to meet the demand at any given time. An indicative target of 20% blending of biofuels, both for bio-diesel and bio-ethanol, by 2025 is proposed. Presently 10 % ethanol is blended with petrol in India.

The main objective of this research is to evaluate suitability of biofuels as an alternative fuel for CI engine. The research article presents the brief information about different biofuels like Biodiesel, Ethanol, Biogas, Producer Gas and Hydrogen. The detail experimental investigation was carried out on IC Engine (Kirloskar TV1 model, 0.661 liters capacity, 5.2 kW at a rated speed of 1500 rpm) using different Biodiesel (and biodiesel blend) like microalgae, Neem oil, Jatropha, Neem oil, Waste cooking oil, plastic oil etc. and the obtained results were compared with the result obtained using diesel as a fuel for the same engine. The different combustion, performance and emission parameters were measured for each test and the obtained results were compared.

A general trend of increase in the brake thermal efficiency (BTHE) with the use of biodiesel blends B20 and B40 is observed at all the loads. B20, B40 and diesel shows the maximum of BTHE of 35.87%, 34.84% and 32.81% at 5.15 kW load respectively, showing 9.31%, 6.18% higher for B20 and B40 than diesel fuel as shown in figure 1.

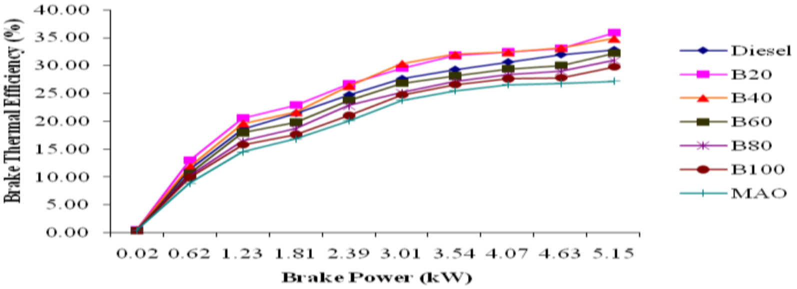

Figure 1: Load vs. Brake Thermal Efficiency

The emission readings are measured with calibrated AVL Digas 4000 light five gas analyzer and AVL 437 smoke meter. The emission analysis of CI engine fuelled with biofuel blends shows reduction in emission of pollutants like HC, CO and Smoke with increase in

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NOx emission.

Similarly the detail experimentation was carried out using biogas, producer gas, ethanol and based on the experimental investigation it can be stated that the biofuels like biogas, producer gas, ethanol and biodiesel can be used as a alternative sustainable fuel for IC Engine.

Hydrogen fuel is a zero-emission fuel burned with oxygen. It can be used in fuel cells or internal combustion engines. Hydrogen combustion produces only water vapor as a byproduct, making it a clean and environmentally friendly fuel. Hydrogen has a high energy content per unit mass, which makes it an efficient and sustainable fuel for IC engines. It has a higher energy density than conventional fuels like gasoline or diesel, meaning it can provide more power for a given weight of fuel. Hydrogen can be used as a fuel in RCCI and HCCI engines.

Reactivity Controlled Compression Ignition (RCCI) engines is a combustion concept that combines elements of both compression ignition (CI) and spark ignition (SI) engines to achieve high efficiency and low emissions. It involves the use of two fuels with different reactivity properties. In RCCI engines, a highly reactive fuel is injected into the combustion chamber using direct injection, while a less reactive fuel is introduced into the intake manifold. The highly reactive fuel, such as diesel or gasoline, undergoes compression ignition, while the less reactive fuel, like hydrogen or natural gas, acts as a diluent and assists in controlling the combustion process. Hydrogen has a high flame speed and wide flammability range, which aids in achieving fast and reliable combustion. Hydrogen also have high octane rating, which means it has excellent resistance to knocking, enabling high compression ratios and improved thermal efficiency. By blending hydrogen with a highly reactive fuel, RCCI engines can achieve high efficient and clean combustion. Hydrogen's low carbon content also makes it an attractive option for reducing greenhouse gas emissions. Additionally, hydrogen combustion produces only water vapor as the main byproduct, making it a clean-burning fuel.

Homogeneous Charge Compression Ignition (HCCI) engine are a type of IC engine that combines characteristics of both spark ignition (SI) and compression ignition (CI) engines. In an HCCI engine, the fuel-air mixture is homogeneously mixed and compressed, similar to a CI engine, but combustion is initiated by compression rather than a spark plug, like in an SI engine. Hydrogen has some unique properties that make it suitable for HCCI combustion. It has a high flame propagation speed, wide flammability range, and a low ignition energy requirement. These properties allow hydrogen to autoignite and burn rapidly when compressed, which is desirable for HCCI operation. When hydrogen is used in an HCCI engine, the intake charge is typically a mixture of hydrogen and air, which is thoroughly mixed to achieve a homogeneous mixture. The compression stroke then compresses the mixture to a high pressure and temperature, causing it to autoignite and undergo combustion. This combustion process is characterized by fast and simultaneous burning of the entire mixture, resulting in a more complete combustion compared to traditional SI or CI engines. The use of hydrogen in HCCI engines offers several potential benefits. Hydrogen has a high energy content per unit mass, making it an efficient fuel. It produces no carbon dioxide (CO_2) emissions when combusted, only water vapor, making it a cleaner option. Additionally, hydrogen combustion produces negligible amounts of nitrogen oxides (NOx) and particulate matter, further improving its environmental impact.

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Optimization and management of an integrated energy system

Katarzyna Gdowska[1,*], Roger Książek[1], Radosław Kapłan[1]

Keywords: energy storage, minimizing cost

ABSTRACT

This article presents advanced methods for optimizing and managing an integrated energy system using photovoltaic panels, energy storage, and hydrogen technology. The article outlines the goals of this system, which include minimizing costs and losses by effectively forecasting energy demand and managing the flow of energy between different sources and storage facilities.

The authors propose the analyzed energy system consisting of photovoltaic panels and the power grid, with energy stored in three types of storage: high-efficiency batteries, hydrogen storage, and thermal storage. The main objective of controlling the system is to minimize the annual operating costs by choosing the most efficient path for the energy flow at any given time, considering the availability and losses associated with each source.

The article shows that the system must decide on using energy from photovoltaic panels, the grid, batteries, and hydrogen technology, considering weather conditions and domestic hot water demand. In addition, the system manages the energy flow between storage units, optimizing the order of their discharge to minimize losses. This considers adverse weather conditions, low battery energy levels, limited electricity demand, and increased heating demand.

The authors also propose using the weather forecast five days in advance, which allows for more accurate forecasting of energy needs. Finally, the article presents a control system that not only ensures energy delivery to consumers but also minimizes losses and operating costs, considering different energy sources and storage. This requires continuous monitoring and real-time optimization, which is a complex task.

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ENERGY FUELS ENVIRONMENT EFE2024
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Influence of altitude and physicochemical conditions on pressure values in a low-pressure gas network

Krzysztof Kogut[1,*], **Piotr Narloch**[2], **Ewa Zięba**[2]

Keywords: pressure recovery, natural gas network, distribution gas network, simulation of gas network

ABSTRACT

Pressure recovery, as a phenomenon related to the density of the medium, can be observed mainly in gas installations. However, the feasibility of pressure recovery in a gas network, where by definition, the gas flow conditions are completely different from those in installations [1], raises doubts.

By definition, pressure recovery is achievable when two equally important conditions are met:

- the difference in density of the media,
- the difference in height between the inlet and outlet points.

Natural gas, which has a lower density than air, moves upwards due to gravity. This phenomenon is enhanced if, for example, the proportion of hydrogen in natural gas increases. This is caused by an additional decrease in the density of such a mixture relative to air [2].

Figure 1 shows a schematic diagram of the network analysed, with the levels marked and the exact heights of each node.

The formula [3] is used in engineering practice for the calculation of pressure recovery in gas installations and was also used in the calculations carried out:

$$\Delta p_H = g \cdot \Delta H \cdot \left(\rho - \rho_p\right) \tag{1}$$

where: Δp_H – altitude-related pressure recovery, Pa,
g – standard gravity, 9.81 m/s^2,
ΔH – altitude difference, m,
ρ – gas density, kg/m^3,
ρ_p – air density, 1.293 kg/m^3.

The calculations were carried out using computer programmes (Stanet, Simnet) for modelling low-pressure distribution networks, and the results obtained were compared with the values calculated based on the defining Darcy-Weisbach equation and the values measured at selected points in the analysed gas network.

Figure 2 shows the results of the calculations obtained from the analyses carried out for the gas flow from the supply point (at the bottom of the network) to the final node in the right arm of the network. For comparison, the results of the calculations when the effect of height is neglected are also included.

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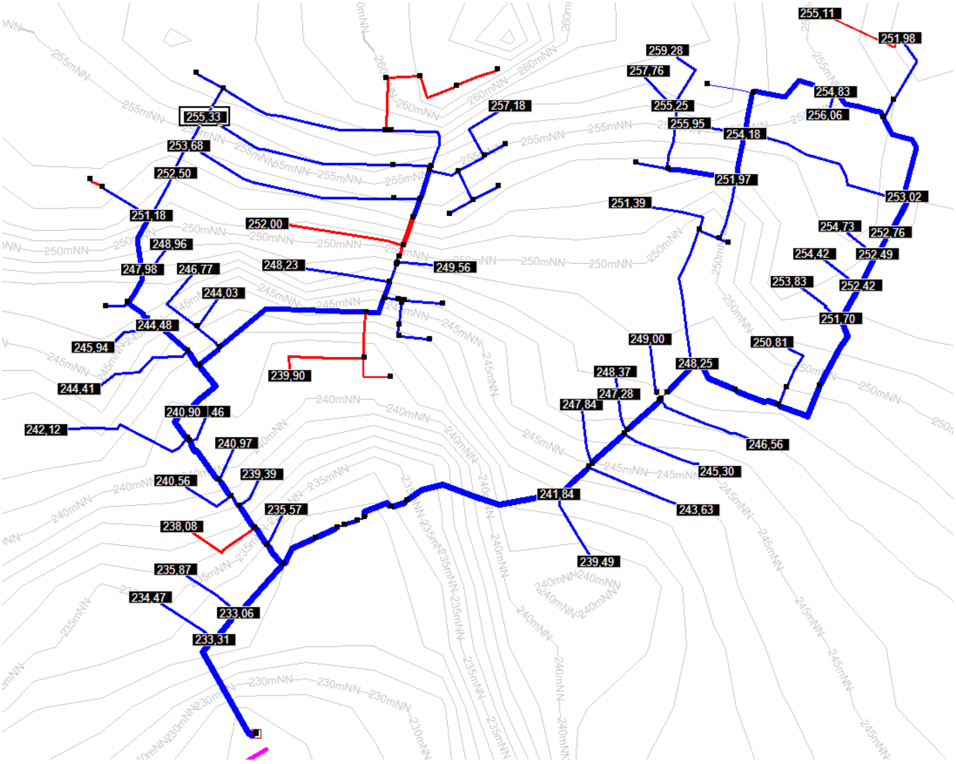

Fig. 1. Network with geodetic heights of nodes

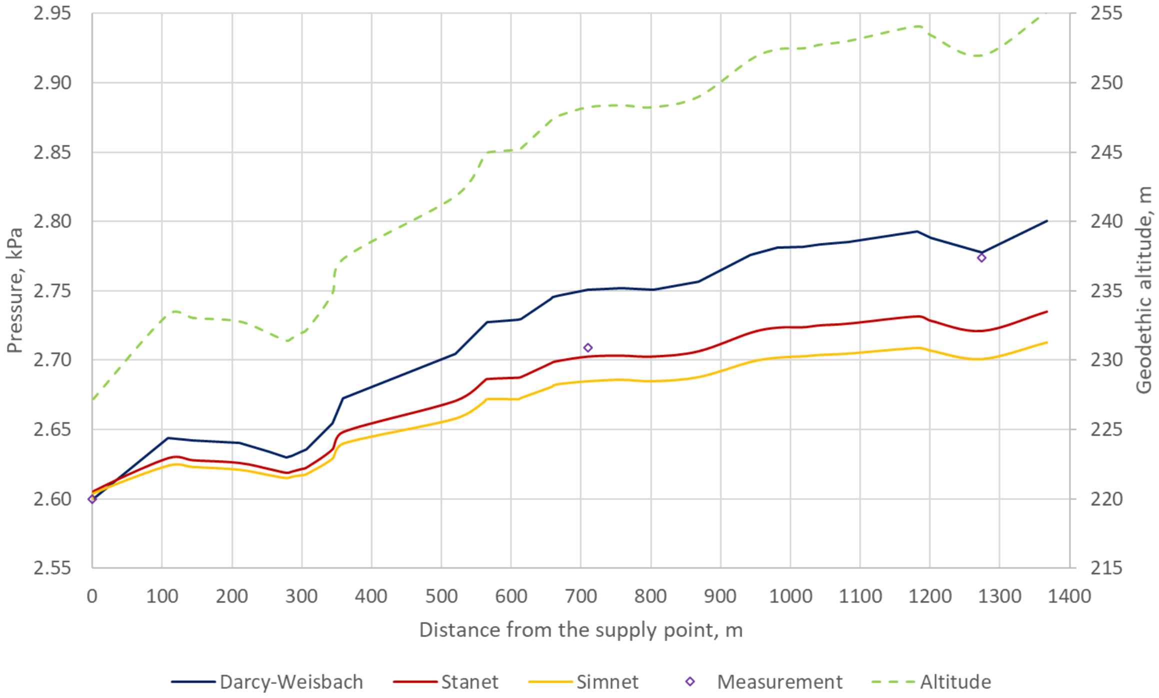

Fig. 2. Calculation results including the effect of altitude

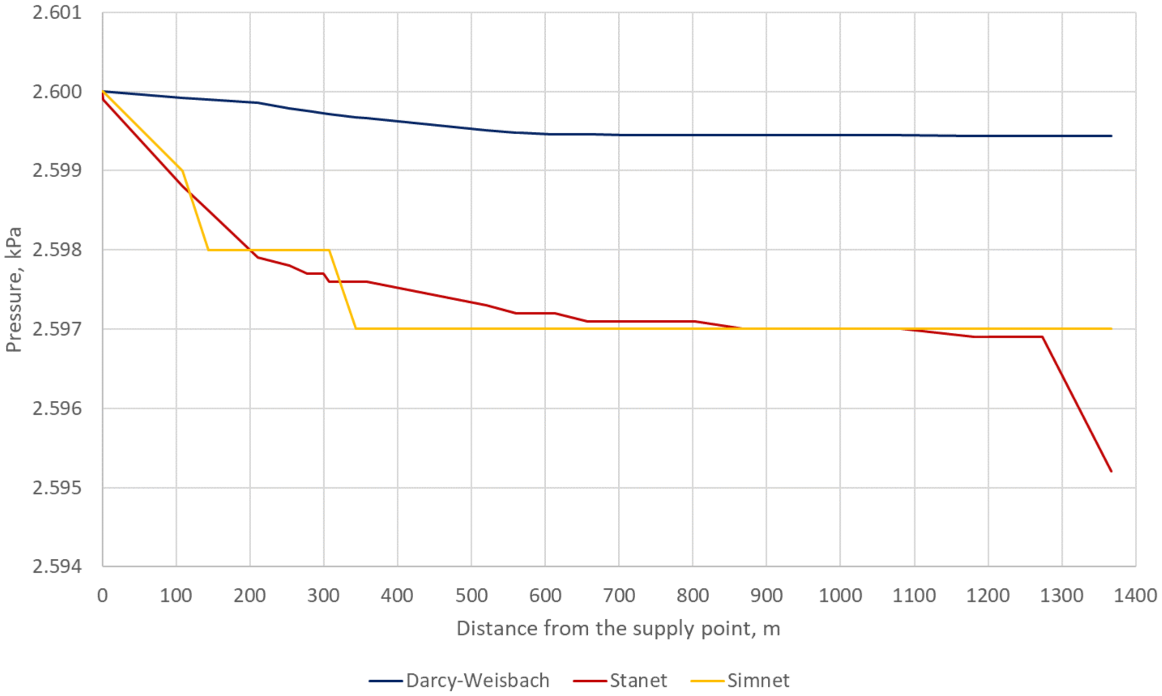

Fig. 3. Results of flat model calculations

Table 1 shows the recovered pressure values obtained for the different calculation conditions. The values calculated when the network is supplied at medium pressure (250 kPa) are also included for comparison.

Table 1. Comparison of pressure recovery

Influence of altitude	Model	Supply pressure, kPa	Pressure at the end of the test section, kPa	Pressure recovery, %
yes	Darcy-Weisbach	2.6	2.8004	7.70
	Stanet	2.6	2.7347	5.18
	Simnet	2.6	2.7130	4.35
	measurement	2.6	2.7740	6.69
no	Darcy-Weisbach	2.6	2.5994	−0.02
	Stanet	2.6	2.5952	−0.18
	Simnet	2.6	2.5970	−0.12
yes	Darcy-Weisbach	250	250.20	0.08
	Stanet	250	249.66	−0.14

Table 2 shows the maximum pressure recovery achievable in the network analysed. The values shown are due to the difference between the density of the gas in the network and the density of the air, as well as the difference in height between the supply node and the terminal node (28 m).

Table 2. Maximum achievable pressure recovery

Medium	Natural gas	A mixture of natural gas and 25% hydrogen
Density, kg/m^3	0.735	0.574
Pressure recovery, kPa	0.1533	0.1975

Analyses carried out using two simulation programmes, calculations using the definition equation, and recorder readings have shown that pressure recovery occurs in low-pressure networks in justified cases and under the necessary conditions. To achieve this, the difference in height between the inlet and outlet points and the difference in density between the air and the medium in the pipeline are required. In order to observe an increase in absolute pressure, as in the case under consideration, additional conditions must be met regarding the flow-induced pressure drop and the pressure recovery resulting from the difference in height or the change in the relative density of the gas flowing through the gas network.

After applying the formulas to determine the recovery/pressure drop from the source to the end node where the difference in altitude of the points is 28 m, depending on the calculation method used, a recovery in the range of 0.113-0.200 kPa was obtained.

The most accurate and complete confirmation of the occurrence of pressure recovery was a comparison of the calculation results with measured data carried out on the same network. The installation of pressure recorders confirmed not only the occurrence of pressure recovery in the low-pressure network but also the calculated values. The pressure recovery measured was 0.174 kPa.

In addition, it should be noted that the phenomenon of pressure recovery is practically unique to low-pressure distribution networks. In the case of other networks, the amount of pressure recovered is so tiny compared to the pressure prevailing in the network that its effect on the final value is negligible.

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Management-technology collaboration on introducing hydrogen technology in railway sector

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Keywords: hydrogen refueling station, railway network, refuelling station location problem, critical infrastructure location, strategic decision-making

ABSTRACT

The implementation of new technologies in a strategically important sector of the economy is an issue that requires advanced multi-level cooperation between management and technology teams. The complexity of the problem arises both from the natural life cycle of the innovation and the successive TRL and MRL levels achieved by the new technology, and from the nature of the management process of strategic decision-making, which involves decisions on costly investments that are considered over the long term. In the case of a strategic sector of the economy, in which state-owned companies are involved, and in which the main development investments are financed from public funds, the importance of the methodological correctness of the decision-making process, including the analyses carried out as part of the decision support system, increases.

Due to the fact that the knowledge and experience of managers play an important role in the decision-making process at the level of strategic management, an abductive approach is used, which allows combining quantitative and qualitative methods. Abduction does not rely solely on existing theories and models, but supports the search for new solutions and ways of thinking, which results in the generation of innovative strategies and unique solutions. Due to the use of quantitative methods, abductive reasoning is particularly useful in situations of uncertainty and volatility, where complete information is lacking, such as in the implementation of a new evolving technology.

An example of the application of the abductive method is the problem of implementing hydrogen propulsion technology in the rail sector, and in particular strategic decisions regarding the siting of hydrogen fueling stations. Site selection is a critical long-term decision involving the choice of locations for one or more facilities within a planning area to optimize specific objectives [1]. It is particularly important when implementing new technologies that may have a significant impact on the sector or the economy as a whole [2].

The research discussed in this paper relates to the abductive methodology developed to study how to support the technology managers of a railway company in the decision-making process about the placement of hydrogen filling stations [3-5]. An important characteristic of the decision-making situation is the scarcity of information, or more precisely, its wide dispersion in the knowledge resources of those who are directly involved in the project or who are its stakeholders. An example of the scarcity of information is the question of the demand for hydrogen, which is generated on the basis of decisions on the hydrogenization of railway lines taken by different companies.

On the other hand, several Mixed-Integer Programming (MIP) models have been developed for the problem of optimal station layout. This approach allows decision makers to analyze multiple scenarios and the optimal solutions derived from them. Acquisition of data instances for practical use of these models faces obstacles at the level of the need to transfer knowledge from operations research (how to properly use such support) to those who may have the necessary information.

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The article presents the concept of an original research methodology involving a workshop for company representatives. The outcome of the workshop is expected to be the development of a format and method of obtaining data through a deeper understanding of the objectives being pursued. Based on the data, solutions will be generated, which in turn will be evaluated for their practical usefulness in subsequent workshops.

The research was conducted as part of the Europe's Rail Flagship Project 4 - Sustainable and green rail systems, WP9 Interoperable Hydrogen Refueling Station, DOI: 10.3030/101101917.

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LOTOS Green H2

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Keywords: green hydrogen, electrolysis, renewable energy

ABSTRACT

The main objective of the Green H2 project is to reduce greenhouse gas emissions by producing "green" hydrogen through electrolysis using renewable energy. The result of the project will be the installation of a modular and scalable integrated hydrogen production, powered by RES and an heat recovery system. In addition, the project will use an innovative energy management system and a DC power bus. Connecting the PV installation and the electrolyser (equipment using direct voltage), on the DC voltage side, will reduce energy losses for DC/AC transformation. The use of a common DC bus will improve the current flow balance in the grid node on the DC side, minimizing the need to purchase electricity from the National Power System. The Project assumes using an innovative system for effective energy management. This system will improve the efficiency of individual devices, which will contribute to the reduction of electricity consumption. The control system for the operation of such configured devices will allow for the simultaneous modeling of performance parameters of individual electricity consumption processes, taking into account their technical and technological limitations, including start-up times, gradients of changes in efficiency / power demand, technical minimums etc. It is planned to develop dedicated algorithms for managing the operation of components powered by direct voltage (DC). These algorithms will enable modeling and control of energy consumption, maximizing the local use of energy generated in RES to power devices connected to the DC bus. By using the integrated IT system for the management of energy resources, the consumption of utilities – electricity and heat – will be reduced, which will also contribute to reducing CO_2 emissions. Project will be located in Gdańsk. The hydrogen produced with the use of energy produced by the PV plant will be fed directly into the refinery hydrogen system and into temporary storage tanks. At present, 100% of the production volume is grey hydrogen received from the steam reforming process however the ability to partially replace it with green hydrogen is important due to the anticipated changes of the regulatory regime. LOTOS Green H2 project will contribute to the transformation of the refining industry towards climate neutrality, in particular through the use of renewable hydrogen. will contribute to the transformation of the refining industry towards climate neutrality, in particular through the use of renewable hydrogen.

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Hydrogen projects as part of the activities of the AGH FENEC student scientific research club

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Keywords: polymer membrane fuel cell, hydrogen, hybrid energy source

ABSTRACT

This paper presents the research results of the student project on hybrid energy sources, which consists of a Li-Pol battery pack and a hydrogen PEMFC fuel cell stack installed in an electric bicycle. This project was carried out by the student scientific group FENEC of the Faculty of Energy and Fuels of the AGH University of Krakow

Fig.1 The photo of an electric bicycle powered by a hybrid energy source with PEMFC hydrogen-oxygen fuel cells

Fig.2 The photo of Riksza H2 - a prototype research platform for zero-emission electric transport with a hydrogen fuel cell stack.

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The photo in Fig.1 shows the first research project to develop a hybrid energy source (consisting of a Li-Pol battery pack and a PEMFC fuel cell stack) to power an electric bicycle. The energy source was installed in the electric bicycle with the hydrogen supply system (hydrogen gas stored in the composite tank with a capacity of 1 litre). Control, measurement and energy management systems were built for the hybrid energy source. The hybrid energy source built (the battery pack plus the PEMFC fuel cell stack) was tested at the stationary station. The current-voltage dependencies for the batteries, the fuel cell stack and the hybrid energy source were determined under different electrical loads. The hydrogen consumption was analyzed for given working conditions. The hybrid energy source was integrated into the electric bicycle, electrical tests of the energy source were carried out during test rides in the environment with a different altitude profile. Energy consumption profiles were determined and correlated with the topographical conditions of the area using GPS. Based on the research carried out, it was determined that the use of the hybrid energy source allows the range of the electric bicycle to be extended to 100 km, compared to powering only by the electrochemical battery with a range of 40 km.

Fig.2 The photo of Riksza H2 - a prototype research platform for zero-emission electric transport containing a hybrid energy source with a hydrogen fuel cell stack supplying hydrogen from a metal hybrid low-pressure hydrogen tank. The idea of this project is to test a zero-emission delivery vehicle for goods in the city. Green hydrogen for the supply hydrogen Riksza H2 carry it is produced from renewable sources.

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