3W • WODA • WODÓR • WĘGIEL

Idea 3W

Water, Hydrogen, Carbon: resources that have built and are changing the world

Bank Gospodarstwa Krajowego, Warsaw 2022

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We are on the verge of a huge transformation. Geopolitical changes, energy transition and sustainability are the global challenges of the 21st century. The challenges we will face as humanity, society and economies.

What our future will look like depends largely on whether we can use available resources in a sustainable way.

The mission of Bank Gospodarstwa Krajowego is to support the sustainable social and economic development of Poland. We were the first to recognise the potential of three resources: water, without which there would be no life on Earth; hydrogen, which is the future of energy; and carbon, which is the backbone of modern technology.

In 2021, we launched the 3W Idea (3W is an abbreviation of the Polish names for water, hydrogen and carbon – Woda, Wodór, Węgiel), which focuses on **synergy – not only of resources, but also synergy of potentials** – technologies, innovative ideas, companies and the people who create them and those who build the space to implement them.

Water, hydrogen and carbon are the foundations of a sustainable future. And the technologies associated with these resources are creating a new, highly promising sector of the global economy: the 3W sector.

97% of the human body is made up of water, hydrogen and carbon. **The 3W Idea is therefore about taking care of ourselves** and the next generation. It's a better tomorrow. It's a better us.

Today, we see that the 3W Idea is becoming a 3W reality, with new technologies and solutions in the areas of water, hydrogen and carbon being part of our sustainable everyday life. **What does the 3W world look like?** You will find out about this in this paper, in which we have focused considerably on the synergy of 3W industrial applications.

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Building a better working world

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https://www.ey.com/pl_pl/law/centrum-kompetencyjne-europejskiego-zielonego-ladu-ey

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Resources for life,
without which the world could not have emerged and developed

Yesterday

Big Bang and the origin of matter

The 2001 space mission of the US agency NASA was designed to collect data on the early universe. Thanks to the WMAP[1] probe, it has been possible, among other things, to establish that the Universe is 13.8 billion years old and to confirm the Big Bang theory, from which the creation of matter began.

When the Big Bang occurred, matter began to form shortly afterwards. Although water, hydrogen and carbon did not appear in the universe at the same time, they were all created directly or indirectly as a result of the Big Bang. These are very primary and basic resources.

WATER

It is now thought that water may have been abundant in some parts of the universe as early as one billion years after the Big Bang.[2] This is much sooner than scientists thought, given that we are dealing not with a single element, as in the case of carbon or hydrogen, but with a chemical compound.

It is likely that water appeared on Earth thanks to comets, which consisted of lumps of ice. As a result of collisions with Earth, transformed it from a hot ball of lava into a blue planet. Another theory states, that the water comes from the solar wind consisting mainly of ions of hydrogen, which, combining with oxygen formed, as a result, this chemical compound.

HYDROGEN

Hydrogen is the oldest of the 3W resources. It is one of the most important chemical elements, of which as much as three quarters of the entire Universe is made up: stars, planets or loose matter found in space. As you can see, hydrogen is the basic building block of our planetary system. It is the simplest element, so it is found virtually everywhere in large quantities. Hydrogen in the Universe forms the atmosphere of stars. But why do we hear so often today about how expensive its sourcing is? Unfortunately, this valuable resource is rarely found on Earth in the form of gas which consists of two-atom H_2 molecules. Such gas for industrial or transport needs has yet to be produced.

CARBON

Carbon and oxygen were not created in the Big Bang, but much later. Both of these elements, present in all living organisms, were created in fusion reactors, i.e. in stars. Early stars were massive and short-lived. Most of their lives were spent synthesising hydrogen, and when this fuel ran out, they synthesised helium, converting it into carbon. When stars die, they distribute the elements of life – carbon and oxygen – throughout the Universe. Non-energetic carbon ranks as the fourth most common element in the universe and is present in all living organisms. There is a difference between carbon as an element and coal, a fossil formed during the Carboniferous period. The word *carbon* refers to the chemical element with the symbol C and atomic number 6, and the word *coal* refers to the black rock formed from prehistoric plant remains and burned as fuel.

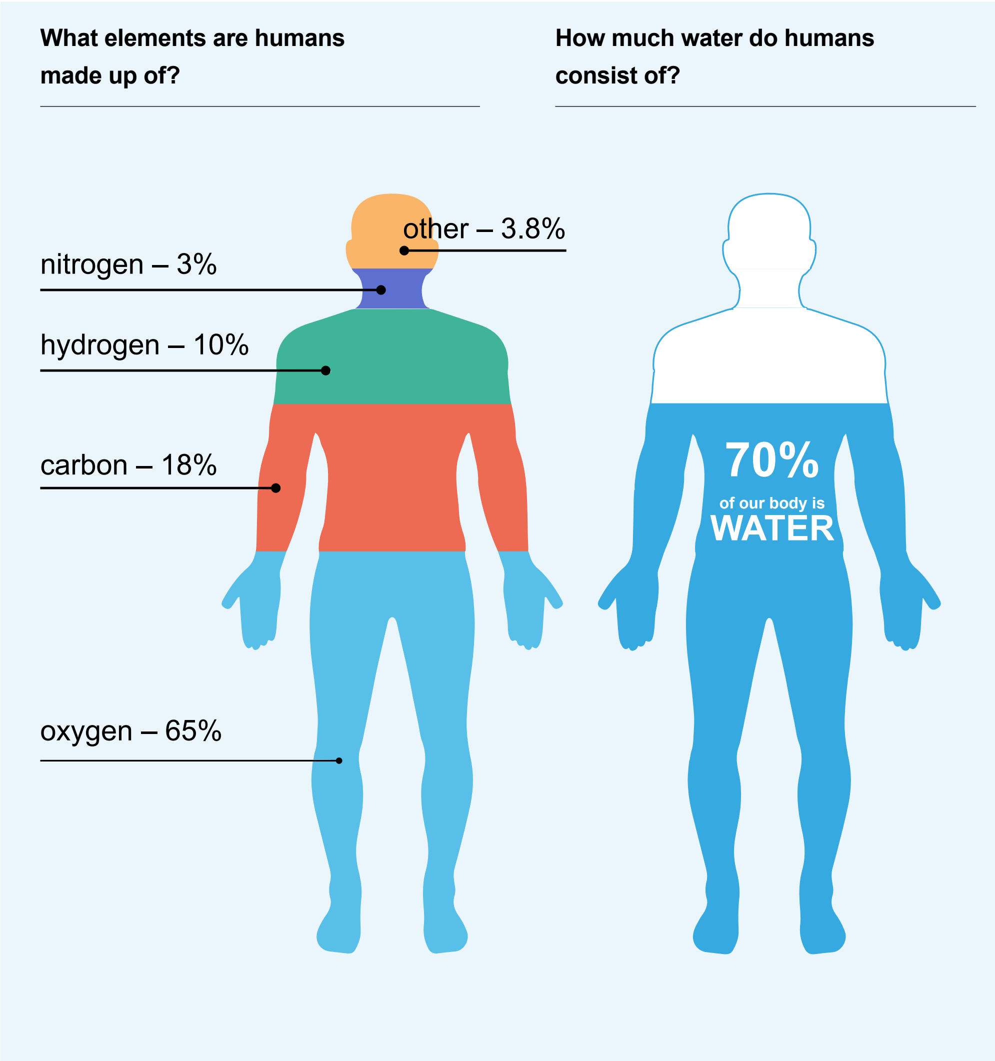
1 Wilkinson Microwave Anisotropy Probe WMAP – Life in the Universe (nasa.gov)
2 Tibi Puiu, *Just one billion years following the Big Bang, water may had been as abundant as it is today* (zmescience.com)

Water, hydrogen, carbon.

Three essential resources from which the world and living organisms were created

Water, hydrogen and carbon are the three resources from which the world and living organisms are made. In terms of biology, life would not be able to arise or function without water and carbon, and carbon and water would not be able to arise without hydrogen. That is why we call these components the resources of life.

Water is an excellent solvent, acting like a conveyor belt to supply the cells with the substances they need to function and remove the unnecessary ones. Carbon, on the other hand, is an element that has the ability to combine into very long chains. This is why all living organisms are made of it. In the human body, the most abundant element – after oxygen – is carbon. We are made up of carbon in as much as 18%. Carbon, as an essential component of organic compounds, is the chemical foundation of life. In terms of biology, both of these resources are essential to us.

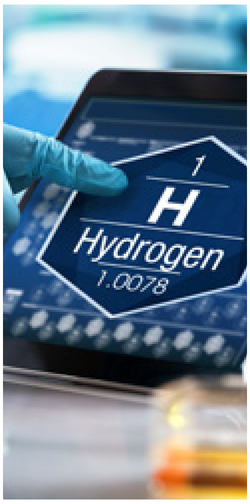


Water, hydrogen, carbon

Early applications in the economy

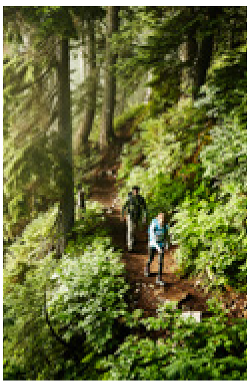
WATER

As the most widespread chemical compound on Earth, water is of great importance for the development of civilisations, which is why access to this resource determined the location of metropolises as far back as ancient times. All of them were built along the banks of major rivers. Mankind was looking for a way to bring water to remote settlements and farmland away from the rivers. To do this, ancient engineers designed irrigation systems and aqueducts. Such methods were steadily developed from 500 BC onwards. The world had to wait much longer for the development of water treatment technologies. The first discoveries in this area did not take place until the 17th century AD. With the growth of industry and the associated environmental pollution, the need for water treatment was ever greater.



HYDROGEN

Hydrogen is the most common element in the Universe and also one of the key substances in many chemical reactions. No wonder the industry became interested in the possibility of using it many years ago. The first research into hydrogen was carried out as early as the 16th century, when the man believed to be its discoverer, Henry Cavendish, obtained it by a reaction between a metal and an acid. Its use on a larger scale began as early as the end of the 19th century during the second industrial revolution, and was linked to economic growth and the emergence of more advanced production methods for fuels, chemicals and food, among others. The methods of hydrogen production used to date have been based on the processing of fossil fuels, mainly natural gas and coal, generating significant amounts of greenhouse gases. The first research into the use of less carbon-intensive methods of producing this resource (e.g. electrolysis) began as early as the mid-20th century, but this method has not yet gained a large market scale. This is largely due to the low price of natural gas and coal, as well as an underdeveloped RES market and transport and transmission infrastructure for hydrogen. That said, it is to be expected that methods of hydrogen production and distribution will change dynamically in line with the idea of achieving EU climate neutrality in 2050.



CARBON

The first mention of the use of non-energetic carbon for medicinal purposes comes from Egyptian papyri dating back to around 1500 BC. Around 400 BC, the ancient Indians and Phoenicians discovered its unique properties and began using it to purify water. The history of carbon fibre began much later, in the 19th century, when Thomas Edison used it in one of the first light bulbs. In 1947, the first theoretical description of graphene was created, but its actual discovery and physical separation from graphite came almost 40 years later. In 1991, Iijima discovered carbon nanotubes, opening a new chapter in science. Scientists around the world are developing new materials using non-energy carbon every day. The latest discovery, a cyclocarbon with semiconductor properties, took place in 2019.

Today

Water today

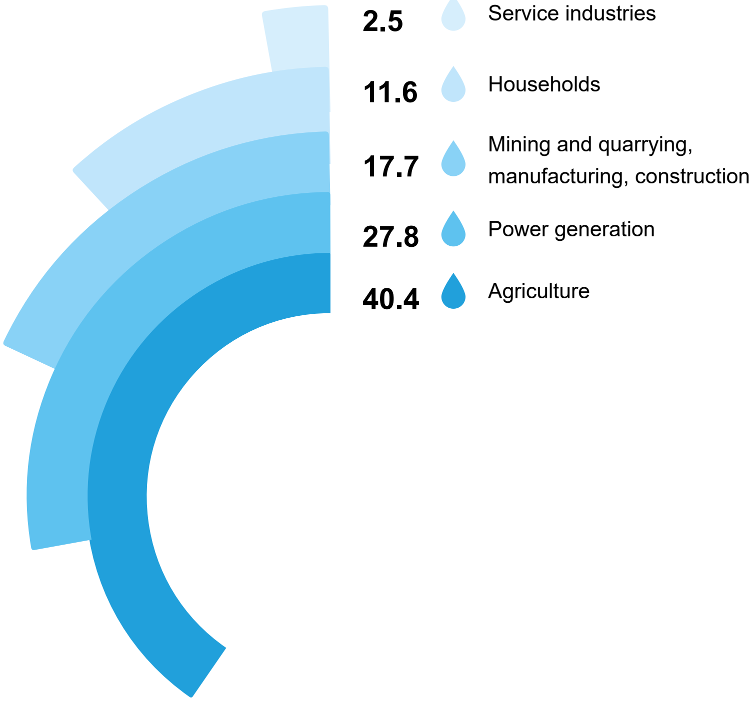
Poland is one of the countries with the smallest drinking water resources in Europe. On a per capita basis, we have 1,600 m^3 of water per year – the same amount as for the statistical resident of Egypt. The significant use of water and its heavy pollution is causing increasing pressure and deterioration of the quality of this resource. According to the Chief Inspectorate for Environmental Protection in Poland, only 10% of rivers have a good or very good ecological status, 60% have a moderate status, while 30% have a poor or bad status.

The unfavourable situation is also exacerbated by climate change. Poland is experiencing more frequent droughts and heavy rains, which can cause local flooding. The activities carried out in the field of retention, which on a national scale should provide protection against floods and secure water supplies for periods of drought, are proving inadequate.

Around 80% of freshwater consumed in Europe comes from rivers and groundwater, and these sources are particularly vulnerable due to overexploitation, pollution and climate variability.

Water consumption by economic sector in Europe

Annual [%]



In the case of Poland, power generation is the largest industrial demand for water, accounting for approximately 25% of the country's annual water consumption. Water is primarily used in coal-fired power plants to cool the power units.

In order to manage the available resources rationally, it is worth considering in which areas of economic activity, apart from the previously mentioned power generation, the greatest consumption occurs.

The water-intensity of the energy sector can be illustrated by the example of Poland's Kozienice power plant, which every three minutes uses the water equivalent to filling one Olympic-sized swimming pool.

Another sector in particular need of large supplies of good quality water is agriculture. In Poland, it accounts for around 10% of its annual water consumption. In addition to the most obvious uses, such as irrigation of crops and agricultural land (cereals, vegetables and orchards), water is essential for raising pigs and poultry. In fisheries and forestry, large quantities of this resource are needed to fill fish ponds and irrigate forest land.

In the food industry, water is used for the production of food itself, but also for cleaning and disinfection. A great deal of water is consumed by the production of meat, dairy products and sweets.

BGK is developing 8 business model programmes to support the implementation of the 3W Idea.

Which of BGK's business model programmes offers such financing?

Industrial Development

SDG:

2 ZERO HUNGER

Food4Future Technologies

One example of a player that is introducing innovative solutions to reduce water consumption in the food industry is Food4Future Technologies. It is a Polish-Norwegian start-up that specialises in modern food production, which is part of the trend towards a circular economy. It focuses its activities on Recirculating Aquaculture Systems. This makes it possible to supply healthy, high-quality products made with respect for the environment. The technology is part of a sustainable production model that responds to major global challenges such as security of supply, increasing competition for natural resources and the risk of farmland scarcity.

The clothing and footwear industry is also extremely water-intensive. It uses water primarily for the production and dyeing of textiles.

In the electrical machinery industry, water is constantly used in production, filtration, softening, chemical treatment, as well as cleaning, washing, rinsing, cooling and hardening of steel.

Water consumption

1 kg of wheat grains	=	1,000 L
1 medium-sized apple	=	125 L
1 kg of beef	=	15,000 L
1 kg of chocolate	=	17,200 L
1 pair of jeans	=	11,000 L
1 pair of shoes	=	8,500 L
1 car	=	379,000 L
1 kg of steel	=	300 L

1 sheet of paper = 10 L

Water is also an important raw material for the wood and paper industry. It is used there for most production processes, including refining and production of pulp and paper.

Utilities sector = approx. 12%

The public sector is responsible for approximately 12% of Poland's annual water consumption. This takes into account the supply of households for domestic purposes, the operation of water supply networks, sewage treatment plants and groundwater intakes.

30%

Approx. 30%
of household water is used to flush toilets

One use of water flush in old models =approx. 9 L

Pharmaceutical industry

Chemical industry = approx. 11%

Mineral industry

The chemical industry is responsible for the remaining approximately 11% of Poland's annual water consumption. Here, water is used for electrolysis and cooling processes, the production of chemicals, chemical products and synthetic fibres. Closely linked to the chemical industry is the pharmaceutical industry. In it, water is used primarily for the formulation of preparations, medicines, solutions, the production of purified water, and it is also used for treatment and sterilisation. Good quality water resources are also crucial for the mineral industry, which mineralises, demineralises and purifies water.

Humans use water in almost all sectors of their activities. For years we were convinced that access to this resource was unlimited. Today, knowledge of water scarcity and the possible consequences of continuing water-intensive activities is widespread. Unfortunately, despite the availability of this data, both businesses and citizens often forget to take firm action to reduce its consumption. The development of technologies to reduce the use and protect this precious resource is the most important issue to ensure a sustainable future for our world.

Hydrogen today

94 Mt*

Global hydrogen production in 2022

2.5%

Share of hydrogen as a fuel in global energy consumption in 2022

1.3 Mt*

Annual hydrogen production in Poland in 2022

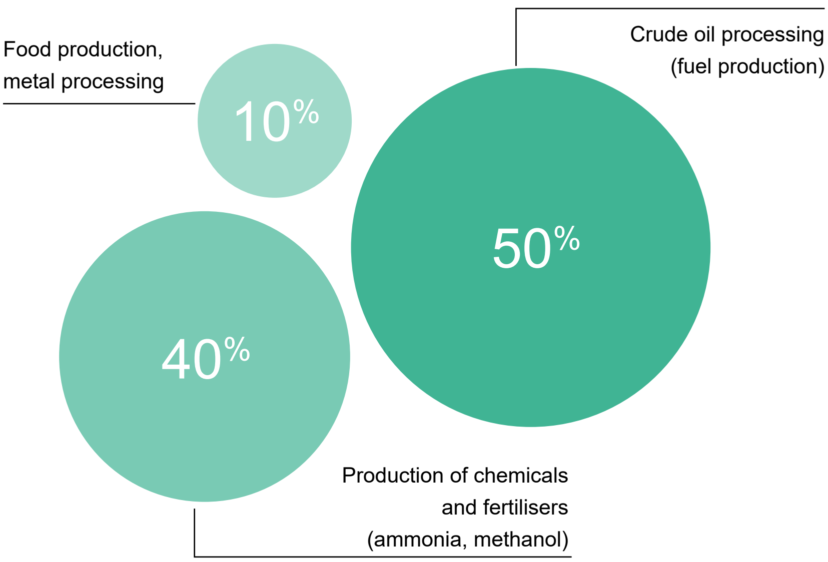
* million tonnes

Hydrogen is a universal element which enables the manufacture of basic products used around the world. Without hydrogen, it would not be possible to produce the fuels that power our vehicles, fertilisers for agricultural crops and much of our food.

Hydrogen is a basic raw material for many industrial production processes, but thanks to its high energy value, it can also serve as a fuel for space rockets. Interestingly, during space flights on the Apollo spacecraft, hydrogen fuel cell technology was used to produce electricity, heat and water.

> "The use of hydrogen enables the production of many key products in the economy. However, it is not currently produced in a fully sustainable and environmentally neutral way. At both global and European levels, the aim is to replace carbon-intensive hydrogen with cleaner alternatives.

Main sectors of industrial hydrogen use



Historically and currently used methods of producing hydrogen for industrial use are based on the conversion of fossil fuels, which results in the emission of large amounts of carbon dioxide. This results in the production of so-called grey hydrogen, the production and use of which adversely affects the environment. Globally, 90% of hydrogen for industrial use is produced from natural gas or coal. The development of technologies that will enable low- or zero-carbon production and use of hydrogen are the most important steps towards a sustainable future for our world.

> "Globally, 90% of hydrogen for industrial use is produced from natural gas or coal.

The use of low-carbon hydrogen in production processes will result in a significant reduction in carbon dioxide emissions compared to the use of hydrogen produced from fossil fuels. At the same time, the new types of hydrogen used can ensure that industrial companies remain compliant with current or upcoming regulations and legislation.

Hydrogen in the chemical industry

Today's chemical industry cannot function properly without hydrogen. However, in chemistry, it is not a final product, but an essential ingredient in the production of two compounds: ammonia and methanol. Both of these compounds are the backbone of the chemical sector both in Poland and worldwide – they are used for the production of fertilisers, among other things.

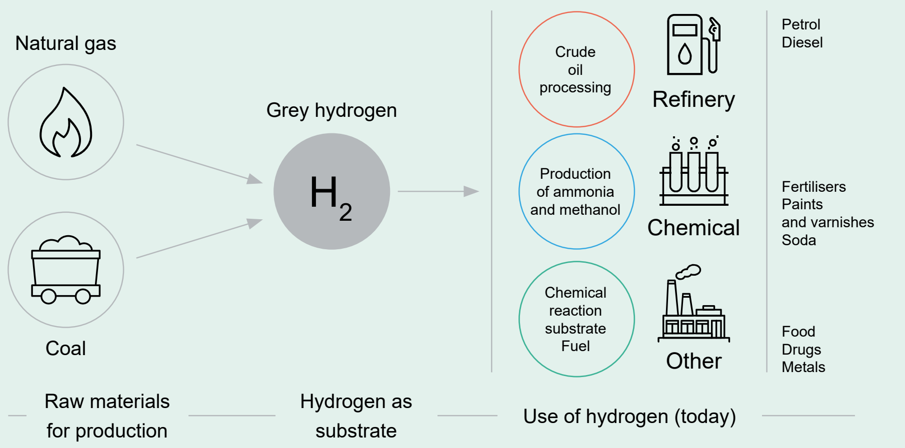
Hydrogen in the refining industry

Hydrogen is also widely used in refinery production. Its primary use is to convert heavy crude oil fractions into lighter refinery products and to purify crude oil of sulphur compounds and other undesirable substances. The production of fuel, as well as petrochemicals, would not be possible without the use of hydrogen.

Hydrogen in other industries

Due to its versatile properties as an energy carrier and component of many chemical reactions, hydrogen is also used in other sectors, such as metal processing, the food industry or the medical field. It is also used as a coolant. However, in terms of the amount of resource used, these industries are much smaller than those listed above, i.e. refining and chemical industries.

Summary diagram of current hydrogen use



Current leaders in hydrogen production for industrial applications

Global leader: China

China produces around 30 Mt of hydrogen per year, placing the country as a global leader. Major concerns producing and consuming hydrogen include Petrochina and Sinopec.

European leader: Germany

Germany produces around 2.5 Mt of hydrogen per year, which positions the country as a European leader. Major concerns producing and consuming hydrogen include Shell, BASF, BP.

Leader in Central and Eastern Europe: Poland

Poland produces around 1.3 Mt of hydrogen per year, which puts it in fifth place in the EU. Major concerns producing and consuming hydrogen include Grupa Azoty, Grupa ORLEN, JSW.[3]

3 The above data and comparison refer only to the current state and production of grey hydrogen.

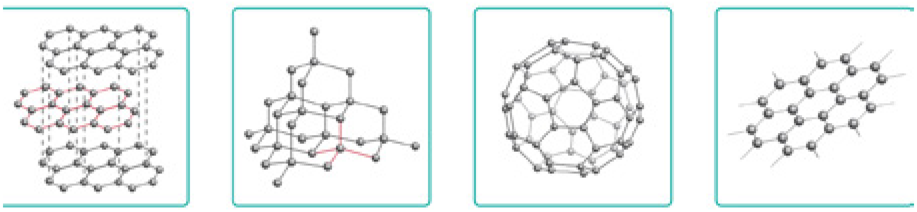
Carbon today

Both the soft graphite in a pencil and the hard, perfectly clear and very expensive diamond are the same element: non-energetic carbon, also known as elemental carbon. This is because some chemical elements, mainly non-metals, can exist in different forms with different physical properties and chemical activities. These are called allotropic forms, and they differ in the structure of the crystal lattice and the number of atoms in the molecule.

A diamond is made up of carbon atoms forming a regular tetrahedral spatial network. Evenly distributed, short yet strong bonds contribute to the very high hardness of this allotrope. Graphite is made up of flat layers stacked on top of each other. Within each layer, the atoms are linked by strong covalent bonds, while between the individual layers only weak interactions occur, which can be easily broken. As a result, the pencil rubs off when we write with it. It is the differences in the spatial lattice that make graphite nothing like diamond.

These are not the only forms in which non-energetic carbon is found. An unusual form of carbon is graphene, or a layer of graphite one atom thick, which is even harder than diamond. Its history is linked to Poland, as it is to Polish scientists that we owe the development of the technology for the industrial production of graphene. This material is extremely strong, flexible and conducts heat and electricity well. Compared to steel, it has five to six times less density, is twice as hard, 13 times more flexible and has 100 times greater tensile strength. Its atomic bonds are so tight that it does not even let bacteria through. At present, the material is very expensive and is being developed by research centres around the world. Graphene, when rolled into a tube, exhibits yet other properties. Nanotubes, as this allotropic form of carbon is called, are particularly resistant to stretching (400 times more so than steel) and also conduct heat and electricity particularly well.

What pencil and diamond have in common: different types of carbon



grafit   diament   fullereny   grafen

In 1985, an experiment by scientists led to the discovery of another allotrope of this element, namely fullerenes. These are molecules made up of an even number of atoms that form a closed block, resembling the appearance of a football. Fullerenes show great potential in drug transport due to their characteristic structure. More recently, another form of carbon, known as cyclocarbon, has been discovered. It is an atomic-sized ring with the properties of a semiconductor. Is this the end of discoveries? In time, we will probably witness new technological developments.

Elemental carbon occurs naturally in various forms, but we can also modify it to get the most out of it. Activated carbon is a form of carbon that has undergone an activation process.

It has exceptional adsorption properties, so that contaminants “stick” to its surface making it ideal for carbon filters in our homes or vehicles. The same carbon, when heated to very high temperatures and stretched, forms so-called carbon fibres, which are used as a structural material for the bodies of Formula 1 racing cars and high-end bicycles. Carbon fibre is stronger and more rigid than steel, yet 80% lighter by weight.

Carbon materials have unique properties, but their production is very energy-intensive. As long as energy comes from fossil sources, their production will be expensive and carbon-intensive. Scientists around the world, including in Poland, are working on technologies that will solve this problem and allow carbon materials to revolutionise the world.

Activated carbon in the battle for clean air – life in Beijing

Beijing is a densely populated city in Asia that has been battling smog for years. In 2016, the quality and clarity of the air was so poor due to smog that the decision was taken to temporarily stop flights. The reason: pilots were unable to see the runway during landing, even from a few metres above the ground.

The onset of heavy smog is caused by the simultaneous occurrence of many factors that accumulate in urban agglomerations (car exhausts, industrial activities and heating systems based mainly on coal). The geographic location of Beijing, which encourages the accumulation of pollutants, is also to Beijing's disadvantage.

The city authorities have taken up the fight against smog and started increased controls to detect cases of burning rubbish, organic materials and even open-air barbecues during a smog alert. In addition, local governments have committed to extinguishing coal-fired power plants and reducing coal consumption. Unfortunately, the problem has not been fully resolved to date and residents are still breathing polluted air.

Smog is a type of intense air pollution and the expression itself is a combination of the words *smoke* and *fog*. Smog contains harmful particulate matter PM10 with a diameter of 10 µm and PM2.5 with a diameter of 2.5 µm. The latter particle is considered the most dangerous to humans, as it is 40 times smaller than a grain of sand and can easily penetrate directly into the bloodstream and impair the body's defence functions. Poor air quality is making Beijing residents increasingly susceptible to illness.

Energetic coal is one of the reasons for smog in Beijing, but it is elemental carbon that shields residents from the adverse effects of smog. In Asian metropolitan areas, the sight of passers-by wearing masks was natural even before the outbreak of the COVID-19 pandemic. These masks have a sewn-in carbon filter.

The same coal that emits huge amounts of pollutants when burned, subjected to a certain thermal or chemical treatment, does an excellent job of cleaning the air.

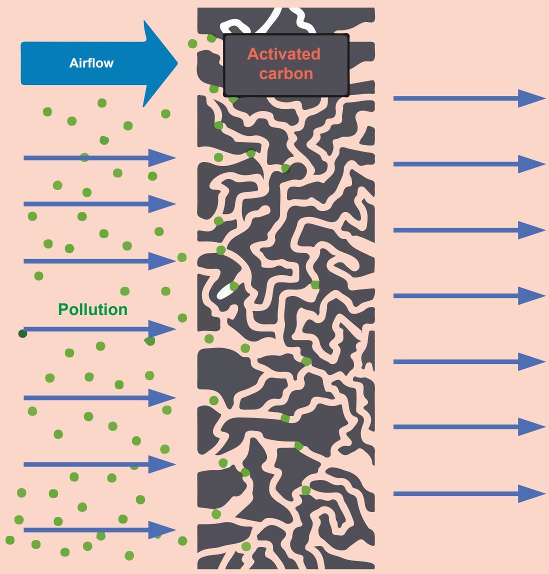
Where is activated carbon used? In all the carbon filters we find in masks, air purifiers, vehicles, domestic appliances... Virtually anywhere that effective air or water filtration is needed. Carbon filters capture impurities from the flowing air or water. And what happens next? Upon filling its entire surface area, activated carbon can be cleaned in a process known as reactivation and reused.

Carbon obtains these unique properties through the activation process described earlier, which serves two purposes. First, it significantly increases the surface area of the material, and then makes it possible for dirt to “stick” to the surface. How is this possible? The size of the surface area (the so-called specific surface area) increases as a result of the formation of a very large number of micropores, tubules and connections in the carbon grain. Then, using the appropriate chemical processes, we give the material its adsorptive properties and it can bind contaminants on its surface.

Carbon is also used for exhaust gas treatment by, for example, factories in and around Beijing. It captures VOCs generated by industrial processes that are hazardous to health. This minimises the progressive degradation of the environment and the negative impact of pollution on the respiratory system of local residents. Given the potential for reducing emissions in a wide variety of economic sectors, modern applications of activated carbon fit in with the goals of sustainable development.

> The activated carbon filter used in air purifiers can remove up to 99.4% of airborne particles.

Air purification through activated carbon



Carbon fibre stronger (and lighter) than steel

Carbon fibre, despite its very high production costs, is readily used in the automotive industry and in the manufacture of sports equipment. Carbon – as this composite is commonly called – is widely used for high-end ski equipment. It is a component of skis, including their outer shell, and acts as a damper for unwanted vibrations. Carbon fibre is used to make some parts of the shell of boots, as well as ski poles, either in part or in full. Carbon fibre can also be found in ultralight tennis racquets and bicycles, such as the ones manufactured by the Polish brand Kross.

Carbon composite is a material that is made by combining carbon fibre with resin. Depending on the production method and the amount of resin used to cure it, it has different parameters. For the material to be sufficiently strong and lightweight, the optimum proportion of ingredients needs to be chosen.

Which of BGK's business model programmes offers such financing?

Industrial Development

SDG:

Rega Yacht

Polish Subcarpathian company builds carbon fibre yachts

In Ropczyce near Rzeszów, the Polish company Rega Yacht has been building carbon composite boats for years. Carbon fibre works brilliantly as a construction material for offshore yachts making the boat light, safe and fast. The main business focus of the company from the Subcarpathian region is the construction of sailing yachts for foreign shipowners. The company also offers repair and refurbishment services. The yachts produced in the Subcarpathian region most often end up in Italy.

The development of technologies that will enable the low- or zero-carbon production and use of carbon-based materials made with elemental carbon are currently the most important challenges.

Tomorrow

What might the world look like depending on how we use 3W resources?

When thinking about tomorrow, we usually look at yesterday and today. On this basis, we assume what the world will look like in the future. In this way, we often unconsciously use extrapolation, i.e. drawing conclusions about the direction of our civilisation on the basis of known technologies or current trends.

The future of our planet and living beings depends on how we use the earth's main resources, i.e. largely how we use water, carbon and hydrogen.

When we described the technologies used today, we often said that they should be more sustainable in the future. Undoubtedly, one of the main criteria we use when thinking about the future is the concept of sustainability. What exactly does it mean and what relevance does it have for 3W?

Currently, the material footprint (i.e. the total resource exploitation) that the planet can withstand is 50 billion tonnes per year, meanwhile in 2017 we consumed almost twice as much – 92 billion tonnes[4].

4 Data from UN International Resource Panel or materialflows.net

Sustainability and green business transformation

In the early 18th century, Hans Carl von Carlowitz worked as chief mining administrator of the manor in Freiberg, Saxony, which was then the largest mining region in the world. Hans was also responsible for the forests belonging to his principal. Unfortunately, trees near mining sites had been felled at an unsustainable rate for decades. As no efforts were made to restore them, this resulted in the old forests disappearing completely! Hans, who recognised the crisis of depleting forest resources, advocated the following use of wood in his book *Sylvicultura Oeconomica*:

> “ Only as many trees as can grow in this place shall be felled, so that the forest is never eradicated, so that it can always rebuild itself.

Although the concept of sustainability originated in forestry, in modern times this idea has been extended to all industries and includes every resource available to man on earth. The first sentence of the report of the World Commission on Environment and Development defines sustainable development in the following words:

> “ Sustainable development is one in which the needs of the present generation can be met without diminishing the chances of future generations to meet them.

The future of humans and our planet depends on how we manage the earth's basic resources. Will we continue to run an economy that exploits resources faster than they can renew themselves?

We know from the previous chapter that currently 3W resources are not always produced and used in a sustainable way. Now let's see what the future might look like when we replace unsustainable ways of operating with sustainable technologies using 3W resources.

Sustainable water use

In order to ensure the availability of resources for a growing global population, it will be necessary to implement innovative technologies to obtain water of sufficient quality. Likewise, a radical change in habits related to its overuse is needed, especially in highly developed countries. In this context, it is worth distinguishing between two fundamental pillars of caring for these resources.

Potable water availability for the entire population

1 ← Proper management of water resources

→ 2 Proper treatment of water resources

The demand for proper management can be achieved by reducing consumption and improving water use efficiency in industry and agriculture as well as in households. Instead of creating technologies that use water in the production process, we should be looking for ones that can do without this precious resource. The demand for adequate treatment can be realised through the development of innovative solutions for, among other things, water treatment and desalination.

Which of BGK's business model programmes offers such financing?

Housing

SDG: 11 SUSTAINABLE CITIES AND COMMUNITIES

AQUARes

The Polish company AQUARes is an example of an entity that combines in its operations the demand for appropriate management of water resources with the need to adapt societies to the worsening effects of climate change. The system it has developed enables significant amounts of water to be effectively collected in the event of heavy rainfall. It helps to protect agglomerations against the occurrence of so-called flash floods, which are caused by particularly intense rainfall and the sealing of the land surface.

The implementation of the system proposed by AQUARes allows water to be retained even before it reaches the stormwater drainage system, thus significantly relieving the burden on municipal networks. Water is stored in vertical tanks on the walls of the buildings, thus reducing the area occupied by the storage facilities. The stored water can be used during periods of prolonged drought.

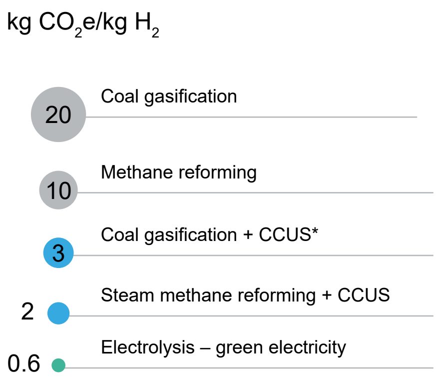
The specifications proposed by the AQUARes system mean that its application can respond particularly effectively to the risks associated with climate change in Poland.

Sustainable hydrogen use

What benefits would a sustainable hydrogen economy bring us?

One of the key objectives for the development of a sustainable hydrogen economy is to reduce CO_2 emissions in production by switching from the use of grey hydrogen – a high-emission substance – to low- and zero-emission hydrogen. It should be noted that the difference in CO_2 emissions with different production methods can be really significant.

CO_2 emissions depending on the method of hydrogen production



* Facilities for the capture, storage and further use of carbon dioxide.

Today, most sectors are set to be decarbonised. In particular, the refining and chemical industries are affected.

Green types of hydrogen will also be found in industries where the element has not previously been used. This includes the zero-emission transport of the future as well as a modern energy industry that is gradually moving away from the use of fossil fuels.

As you can see, hydrogen will be used in many sectors of the economy, ultimately providing a significant reduction in carbon emissions and leading to climate neutrality.

> “
>
> According to the EU Taxonomy guidelines, hydrogen considered to be compliant with EU climate policy must originate from production processes whose emissions are less than 3 kg $CO_2e/kg\ H_2$. Low-carbon and renewable hydrogen fall under this limit.

Green production of carbon-based materials

Sustainable management of raw materials

Can materials derived from carbon be "green"? Of course. Scientists around the world are developing solutions that will allow us to use these unique materials without causing undue harm to our planet.

Carbon is not only found in fossil resources. It is found in plants, agricultural waste, sewage sludge and even nut shells. Let's look at a waste product that could become a precursor to the production of advanced flexible electronics. Sounds abstract, but it's already happening! Under the EU-funded GreenLight project, a method has been developed to produce carbon fibres from lignin – a waste product from paper production. Another example is the method currently being developed by researchers at the Technical University of Łódź to produce graphene quantum dots from... grass.

It is not only the development of less carbon-intensive technologies that matters. Also, the use of green energy from renewable sources can significantly reduce the carbon footprint during production.

Sustainable materials are those that also fit with the principles of the circular economy. Once they have been used, they are not waste but raw material, suitable for reuse. According to data provided by Decotec, emissions from the production of the new activated carbon range from 7 to 13 tCO_2eq per tonne of final product. In the case of recycled activated carbon, this is only 1.03 tCO_2eq per tonne of product.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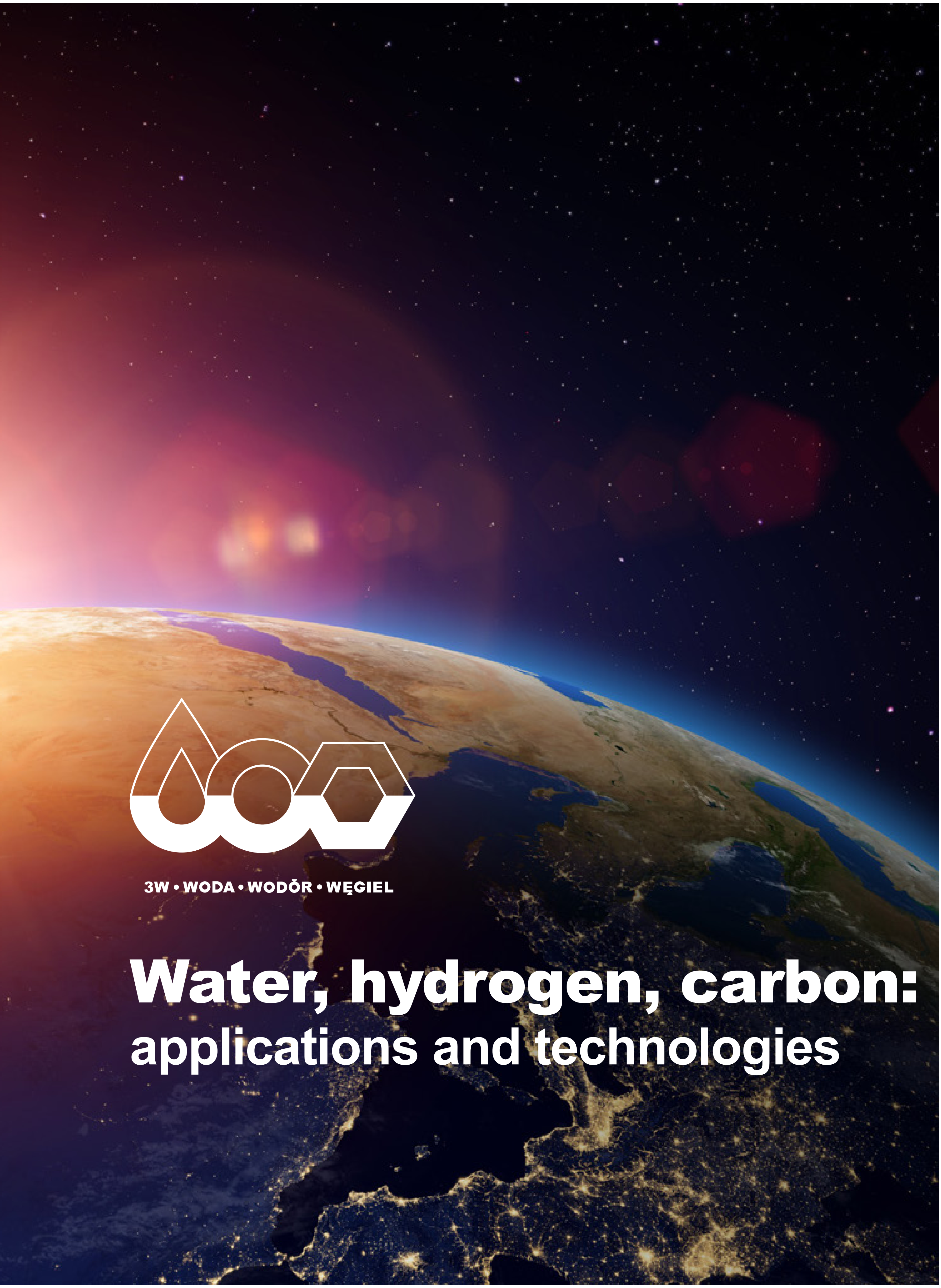


3W • WODA • WODÓR • WĘGIEL

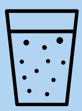
Water, hydrogen, carbon:
applications and technologies

Not only tap water

How to recognise water quality?

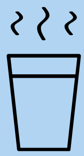
There are no water resources in nature that are suitable for all uses. For this reason, appropriate treatment technologies are required. By knowing and understanding water properties, it is possible to determine its quality and potential uses. It is therefore useful to know the special features of utility water before learning about the process required to obtain it.

Water quality can be determined by verifying its key physical and chemical indicators. In terms of physical indicators, the most important will be turbidity, colour, taste and odour as well as temperature.



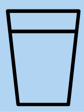
Turbidity

It is caused by the presence of fine solid particles or insoluble inorganic and organic substances.



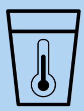
Taste and odour

They are the result of inorganic compounds (e.g. salts and acids) dissolved in water. They may also be due to the presence of organic compounds of anthropogenic origin (e.g. petrol, paraffin, chlorine).



Colour

It is dependent on the presence of coloured organic substances, primarily iron, and other metals. Chemically pure water has no colour. When the water is polluted, it usually turns a greenish colour.



Temperature

This parameter is particularly important for thermal technology (refrigeration) and in the food industry.

In addition, chemical indicators are also worth specifying:

Reaction

Indicates whether the water is acidic or alkaline. For natural waters, it generally ranges from 6.8 to 8.5 pH. Consuming water with the correct pH enables the correct acid-base balance to be maintained and is particularly important for health.

Oxygen consumption

This indicator is conventionally used to determine the organic matter contained in water and is expressed in units of oxygen per volume of water (mg O_2/l).

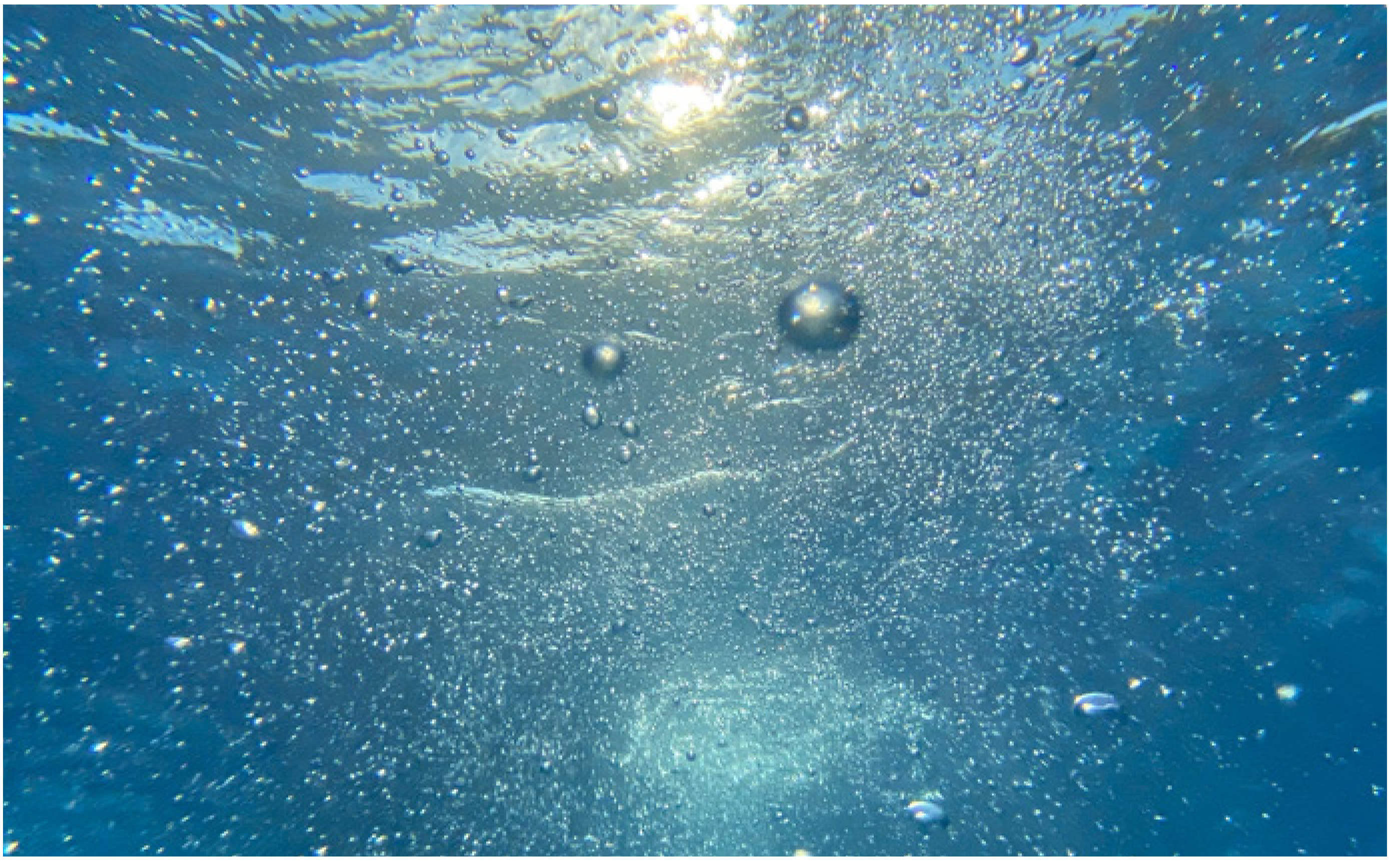
Alkalinity

This property is imparted by the bicarbonates and hydroxides of calcium, magnesium or sodium present in the water. High alkalinity of water counteracts corrosion and its determination is important for economic and technical purposes.

Hardness

It results from the concentration of salt, calcium, magnesium and other metals in the water. In most intakes in Poland, the water is characterised by high hardness. Hard water has ahigher surface tension, which makes washing and cleaning more difficult and forces additional consumption of cleaning and washing agents.

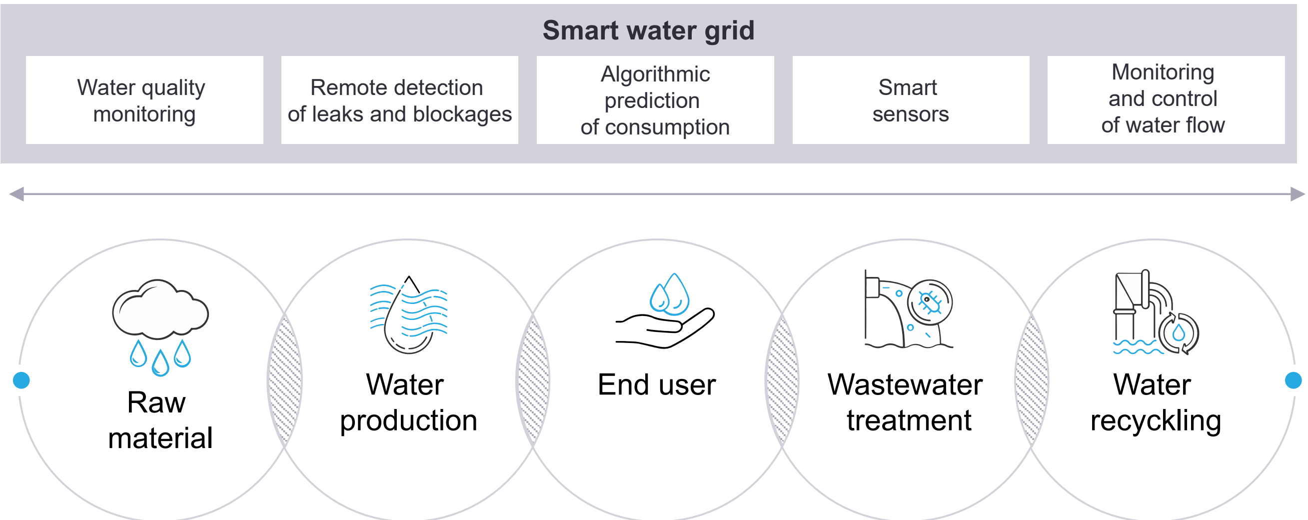
Determining the properties of the water is crucial in order to select the appropriate treatment process and bring it to a state suitable for the needs of the user. The ability to assess the condition of water resources is also extremely useful in everyday life and can allow us, for example, to get rid of our fear of consuming tap water.



What does the water cycle look like?

When considering the future use of water, it is important to distinguish it from the other 3W resources. We are learning about the importance of hydrogen and carbon, and considering further innovative solutions that contribute to the wider integration of these resources into the economy.

With water, on the other hand, the situation is different, as mankind has used enough of it. We should now consider how we can reduce its use and protect current resources. Determining the properties of the water is crucial in order to select the appropriate treatment process and bring it to a state suitable for the needs of the user. The ability to assess the condition of water resources is also extremely useful in everyday life and can allow us, for example, to get rid of our fear of consuming tap water (treatment, desalination) or, after use, to discharge it back into its sources (waste water treatment). These processes are also complemented by water retention, which allows rainwater to be collected, and water recycling technologies that allow water to be recycled and returned to natural resources. All of these processes can be monitored and managed more effectively through the use of modern smart water grid technologies.



The water we use comes from four main sources: groundwater, rainwater, rivers and lakes and the seas. Water consumers can be divided into three main groups: households, industry and agriculture. The use of water in each of these sectors requires different processes to be carried out in order to achieve the right quality for each sector. In this context, it will be particularly important to develop modern technologies so that we can manage resources well. This will allow us to protect existing resources and avoid waste.

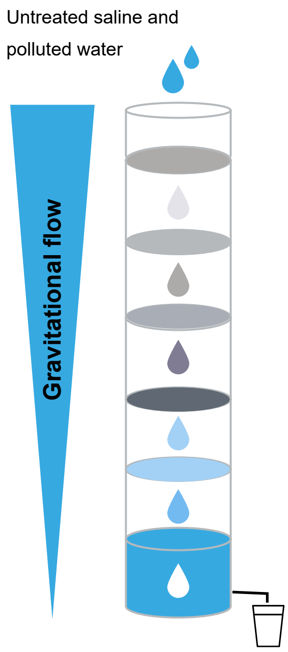
As there are many innovative processes to achieve adequate water quality, in this study we will present those that are the most important and interesting.

Will seawater help meet the needs of mankind?

Desalination is the first necessary process to adapt seawater for use. Desalinated water is distributed through the water supply system, is then further treated and finally reaches final consumers for use.

The spread of desalination technology over the Baltic Sea could be particularly beneficial, due to the relatively low salinity of that sea. The cost of seawater treatment is largely determined by the degree of salinity. Therefore, the potential expenses associated with this in the case of the Baltic Sea will be much lower than, for example, in the case of the Mediterranean Sea, as the latter is roughly three times as salty.

Step-by-step cascade water purification and desalination



Since 97% of the Earth's water supply is salt water and mankind currently uses only 1% of the available supply, it would seem that investment in such technologies would provide us with a solution to the drinking water shortage for years to come.

Unfortunately, the reality is that the development of desalination technology is associated with a number of problems. At present, these are primarily due to the high cost of this type of investment. Their use will only be viable in areas close to salt water. Energy is also an additional concern here. Approximately 10 times more energy is required for the desalination process than for extracting water from any other source. Industrial desalination plants often need their own power plants. The cost of this process is well illustrated by the example of Spain, where desalination plants were abandoned after farmers objected to paying such high prices for water.

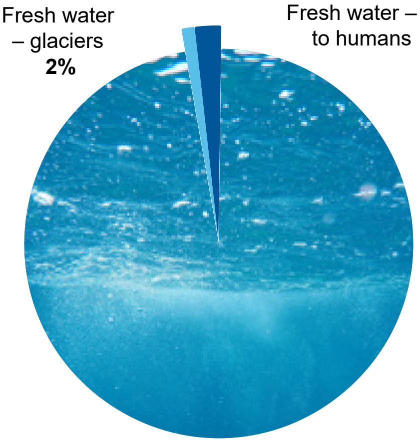
Which of BGK's business model programmes offers such financing?

Entrepreneurship Development

SDG:

Nanoseen

This Polish start-up could become a leader in desalination technology: Nanoseen has developed the world's first non-powered seawater treatment technology. Thanks to the filtration technology, the water becomes potable within 2 to 5 minutes. Meanwhile, the average cost of adapting 10,000 litres of water for consumption is $1[5].



5 Nanoseen, NanoseenX, https://nanoseen.com/en/nanoseenx/ (accessed: 06/09/2022).

However, despite the apparent drawbacks, desalination innovation is the future of water technology. We just have to remember to treat them as a last resort or emergency measure. Its use should be part of a broader plan involving the reduction of water consumption and the conservation of existing resources. Investment in desalination is necessary, but should not be seen as the main solution to the problem of potable water scarcity.

A short history of waste water treatment

As discussed above, technologies such as desalination allow us to obtain water of the right quality and use it for domestic, industrial or agricultural purposes. But what happens to water that has already been used and polluted?

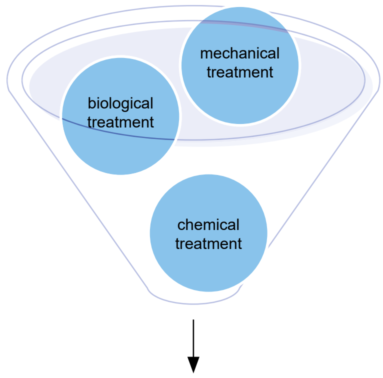
Once the water has been used by end users, waste water is generated, which, together with rainwater from city streets, goes to local treatment plants. Thanks to advanced technological processes involving mechanical, biological and chemical treatment, the water can be returned to its source, such as a river or lake. Then the whole process of using it can start again.

Scientists have already developed a number of technologies to obtain water of the right quality and to treat it properly. In highly developed countries, an average of 70% of municipal and industrial waste water is treated before discharge into the environment. Therefore, the average European may be convinced that the problem of untreated sewage poisoning the world's waters is not so important.

Oceans also have the ability to self-clean and, to a certain extent, nature deals with toxic substances on its own. However, the share of treated waste water entering the environment from developing countries is only about 33% of all waste water. For the least developed countries, the figure drops dramatically to just 8%. Thus, looking globally, more than 80% of waste water is discharged to the environment untreated[6].

Globally, more than **80% of waste water** is discharged to the environment untreated.

We need to treat potable water and good quality water as a finite resource that could run out in the future if we all do not make an effort to reduce its consumption. Action to reduce water consumption and protect current resources should be the first step towards water security.



6 *United Nations World Water Assessment Programme, The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource,* UNESCO, Paris, 2017, p. 2.

Water retention and recycling

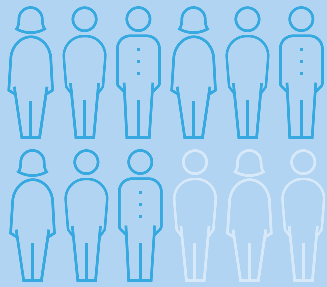
Layers of greenery covering the roofs of buildings allow for improved natural rainwater management. Green roofs absorb rainwater and then evaporate it, increasing the humidity in the air. This natural retention relieves the pressure on the city's sewage system, which further prevents flooding. Moreover, urban oases also produce oxygen and absorb carbon dioxide. A 15 m^2 roof covered with vegetation can produce oxygen for as many as 10 people in a year!

Green roofs are a technology that everyone would like to see on their own residential building or workplace, most likely. Gardens created on the roofs of buildings can become the answer to the challenges of increasing urbanisation and the lack of green areas. The oases created are a valuable resting place for the local community. However, in addition to their leisure benefits, their use also brings significant environmental benefits.

Green roof with an area

of 15 m^2

can produce oxygen for as many as 10 people in a year



The creation of such green spaces counteracts the "heat islands" that are common in cities. "Heat islands" arise in agglomerations due to the accumulation of high temperatures in walls and on the roofs of buildings. As a result, the temperature in city centres rises and the humidity falls. A green roof creates a barrier by evaporating water and reflecting solar radiation. At the same time, acting as additional thermal insulation, it protects the interior of the building from excessive heat loss. Furthermore, green roofs reduce street noise and can provide effective protection against the elements.

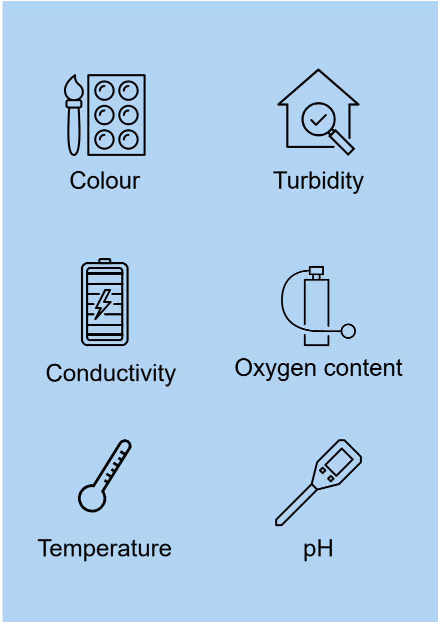
Unfortunately, not all roofs of today's city buildings can become green oases in the future. One square metre of eco-roof can weigh up to 500 kg, i.e. considerably more than traditional structures. It is worth thinking about installing a roof garden as early as during the building design stage. This way, the entire structure can be adapted to meet the necessary requirements.

Greening urban agglomerations is possible and will certainly benefit both the environment and local communities. For this reason, the potential of these emerging technologies is worth pursuing.

Modern technology and water resources

All of the solutions presented have one key area in common – the possibility of using modern IT technologies to improve the efficiency and effectiveness of water management.

Ongoing digitalisation is changing every sector of the economy, including the use of water resources. State-of-the-art technologies for the water sector enable a precise response to the needs of end users, facilitate regulatory compliance, improve efficiency and ensure the reliability of the services provided. A key technology enabling the digitalisation of the water sector is artificial intelligence. It enables real-time monitoring of water consumption or quality, continuous process control and provides better forecasting results[7].



Which of BGK's business model programmes offers such financing?

Entrepreneurship Development

Waterly

Innovative water quality monitoring systems are also being developed in Poland. In this context, the activities of Waterly, a start-up, are worth noting. The monitoring system developed by the company is expected to provide complete information on water quality. Through its use, any interested party will be able to check whether bathing in a lake, river or sea is safe for the body and whether the current water quality allows for the continued development of local fauna and flora. The Warterly system will consist of autonomous measuring stations with sensors analysing specific water parameters such as oxygen content, turbidity, hardness, acidity, salinity, temperature or colour. The metering stations will use the latest technology designed for the Internet of Things (IoT), enabling them to continuously transmit the necessary data. The system's connection to the internet is much stronger than that of standard mobile phones. Based on the data obtained, Waterly determines a water quality index, which the company says will be made available for free to anyone interested.

There are many more technologies such as those proposed by Warterly, and the range of applications is very diverse. In the future, we should invest in their further development at every stage of the water cycle. In the years to come, this will be key to ensuring continued access to water for all consumers. In order to make the right investment decisions, it is essential to determine the financial and environmental viability of each measure.

Which of BGK's business model programmes offers such financing?

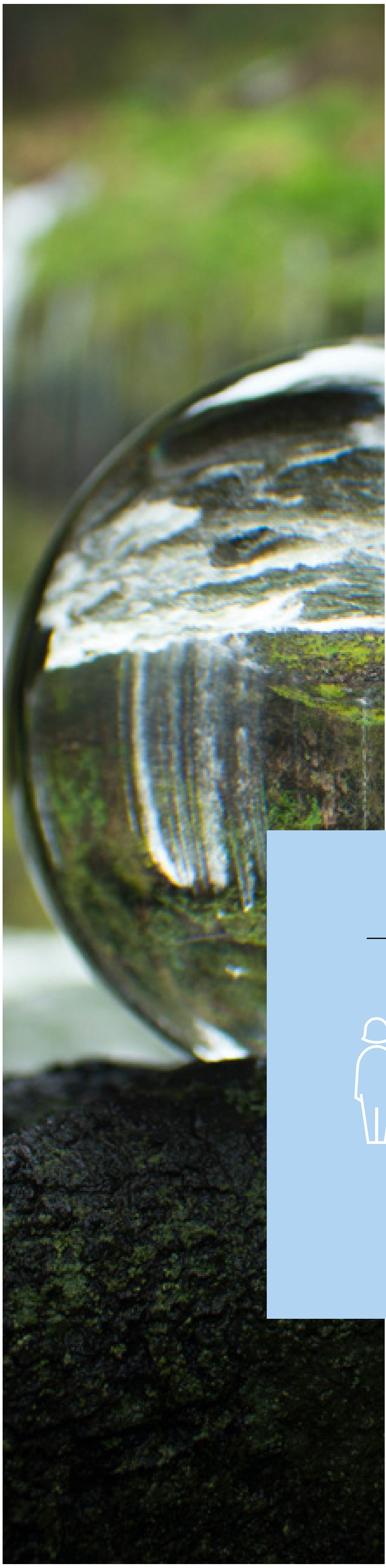
SDG:

Entrepreneurship Development

Ścieki Polskie

Another interesting example is Poland's first digitisation system for liquid waste management developed by Ścieki Polskie sp. z o.o. Its implementation makes it possible to obtain and transmit detailed information on the waste water cycle, from generation to treatment. The system allows data to be passed on to those responsible for waste monitoring. This enables them to effectively manage the most important stages of their circulation.

7 *The International Water Association, Digital Water. Artificial Intelligence solutions for the water sector,* 2020, p. 5.

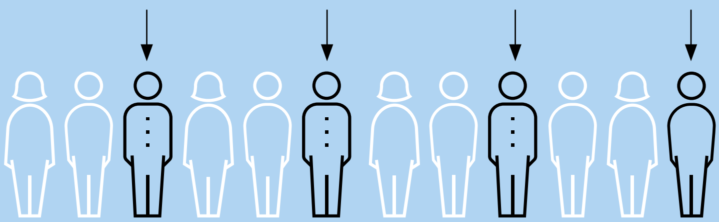


Benefits of water technology development

The development of innovative technologies to produce water of adequate quality is essential to ensure water security in the long term. Today, one quarter of humanity lives in areas where water is likely to become a scarce commodity.

The use of modern technology can significantly reduce areas of freshwater scarcity. At the same time, these technologies will enable many of the goals that the international community wants to fulfil by 2030. All of these goals have been detailed by the United Nations and defined as the UN 2030 Sustainable Development Goals. Improving access to water resources will help achieve many of these.

No access to potable water



1 in 3 people

do not have access to potable water where they live.

Water and the Sustainable Development Goals

WATER...

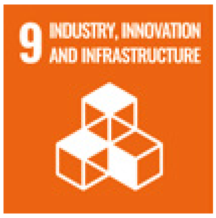
...especially potable water, can improve the safety and hygiene of people around the world by providing better sanitation, thereby contributing to the fight against global poverty.

...as an indispensable resource for agriculture will also reduce hunger, especially in the areas most in need of support.

...free from all micro-organisms, parasites and substances that pose potential health hazards will improve the quality of life worldwide.

...global access to it has been explicitly identified as one of the main goals of the UN.

...is important for the power industry, particularly in connection with power plant cooling processes, but also for hydropower.



...is essential to production processes in almost all sectors of the economy. Thus, its accessibility contributes to the development of innovation, industry and infrastructure.

...has a special role in the blue-green infrastructure. It contributes to climate change adaptation and increased retention and is an important element of sustainable rainwater management, thus ensuring a better quality of life in cities.

...is an essential element for the proper development of biodiversity and the preservation of the environment.

... water also permits the safe development of organisms living underwater...

...and on land.

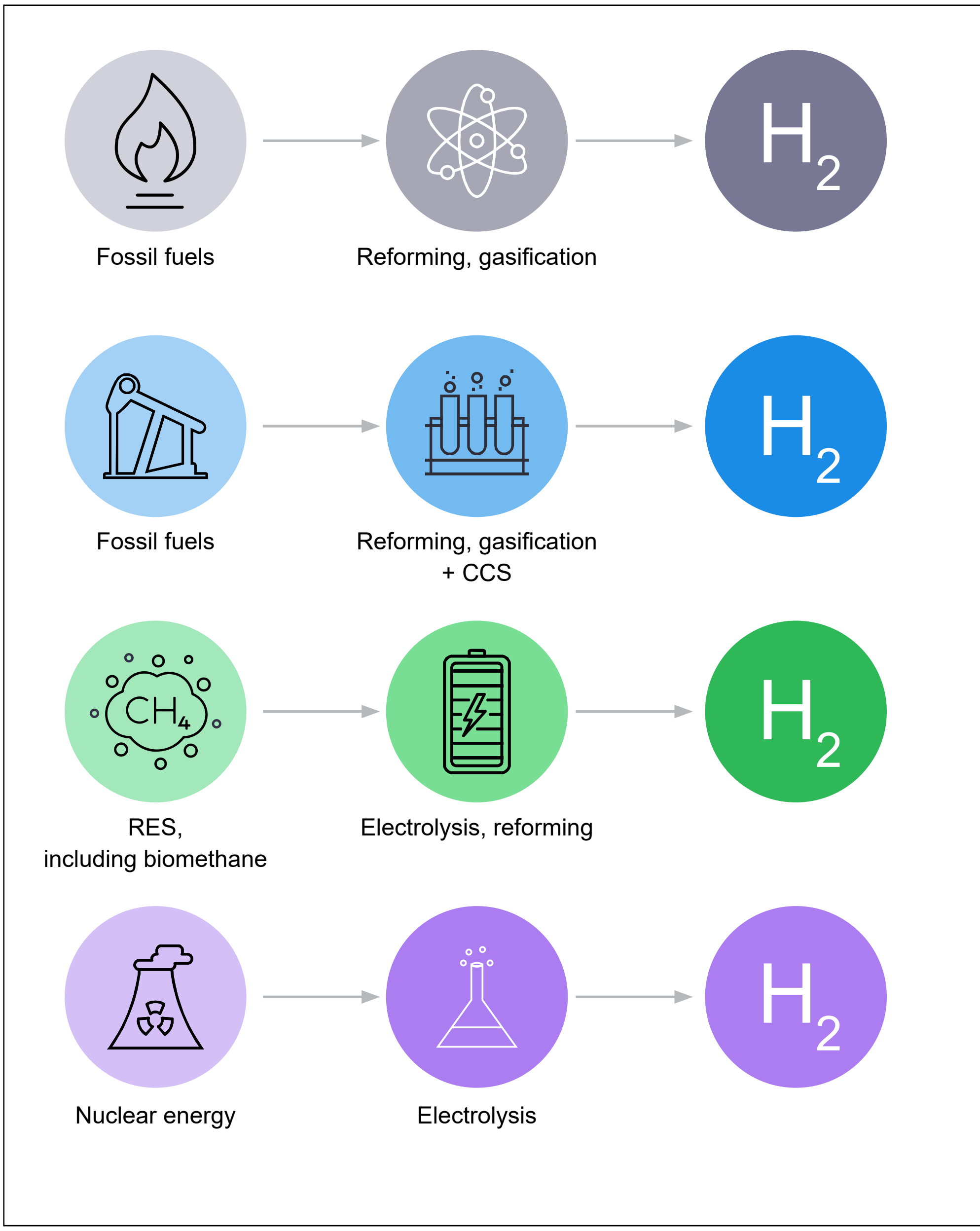
Hydrogen: an element for the future

All colours of hydrogen

Although hydrogen itself is an odourless and colourless gas, we often speak of its different shades. What is the source of this colourful nomenclature and are we actually dealing with different types of this fuel?

Despite the "colourful" descriptions, there is no special difference between different types of hydrogen. On the other hand, due to emission reduction targets and the move towards a sustainable economy, not only the purity of hydrogen, but also its extraction methods are becoming increasingly important in hydrogen production. Therefore, currently one of the main criteria when evaluating hydrogen is the possibility of its environmentally friendly production. This means that, depending on the carbon and energy intensity of the process of obtaining this resource, we can talk about a whole palette of shades!

In other words, hydrogen colours are "eco-labels" that identify the source of energy used in the production process, the raw material used and the overall climate impact of the method. The most common colours in the palette are grey, blue, green and purple hydrogen.



The most popular hydrogen colours ranked according to their climate and environmental impact (from least environmentally friendly to most climate-neutral).

GREY HYDROGEN	Currently, this is the most common way of obtaining hydrogen, unfortunately the most emission-intensive. This type of hydrogen is created from fossil fuels such as natural gas or coal in a process called steam reforming. During this process, water vapour reacts with methane and the products of this process are hydrogen and carbon dioxide. The latter is released directly into the atmosphere. Since every tonne of hydrogen extracted produces 10 tonnes of carbon dioxide, this method is extremely detrimental to the climate and is therefore to be curtailed.
BLUE HYDROGEN	It is also generated by steam reforming, which produces carbon dioxide in addition to hydrogen as a by-product. However, to reduce pollution levels, CO_2 is captured and stored using a technology called Carbon Capture and Storage (CCS). As the blue hydrogen generation process does not actually prevent the production of greenhouse gases, it is often referred to as “low carbon”. Also due to the uncertainty of the long-term effects of CO_2 storage, it is considered a transitional way of producing hydrogen.
GREEN HYDROGEN	It is generated by the electrolysis of water. During electrolysis, only oxygen and hydrogen are formed from water. The electricity needed for this is generated from renewable energy sources, for example wind power, hydropower or solar energy. As both the electrolysis process and its products and the energy used do not generate CO_2, green hydrogen is climate-neutral. This is one of the two hydrogen generation target methods indicated in climate policies.
PURPLE HYDROGEN	It is created using the high temperatures of nuclear reactors, which are then used in the pyrolysis of methane. The product of such a reaction is solid carbon and hydrogen. This method, similar to the green hydrogen indicated above, is emission-free and is the second targeted means of producing hydrogen in climate policies.

What can work on hydrogen?

Transport: hydrogen or batteries

Previously identified as a versatile energy carrier, hydrogen can also have wide application in transport as an alternative fuel providing reduced CO_2 emissions compared to the use of fossil fuels. Hydrogen has a high calorific value, higher than standard fuels such as petrol, diesel or natural gas, which is why it is assumed to be one of the key options for decarbonising transport

> “Hydrogen could be the zero-emission fuel of the future powering global transport.

Another option discussed for reducing emissions in transport is the use of battery propulsion systems based on lithium-ion or newer generation batteries. As a result, the potential for hydrogen and batteries in future transport is often subject to point-by-point comparisons.

At present, it is hard to conclusively identify the winner of the competition: hydrogen or batteries. It seems that both types of propulsion will be around in the future. The differences between hydrogen and batteries can be at the level of application in different modes of transport, and the main selection factors will be the range required, energy consumption, total weight allowed and refuelling/charging time.

Among the key challenges of using hydrogen in transport, the high energy losses in hydrogen conversion processes and the relatively underdeveloped infrastructure are cited. As far as batteries are concerned, the disadvantages are the long charging time and the relatively low range with the high unladen weight of the vehicle.

Market and scientific research to date indicates that hydrogen could be the green fuel of the future especially in heavy transport, as well as transport by rail, sea, air and bus. It should be noted here that in many transport sectors, hydrogen will not be used as a target fuel, but as a base raw material for the production of derived fuels such as ammonia, methanol and synthetic fuels.

> “Hydrogen could be the green fuel of the future especially in heavy transport, as well as transport by rail, sea, air and bus.

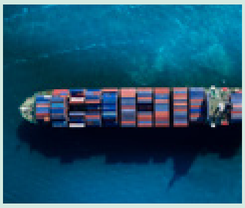
Mode of transport	Fuel type	Estimated time-to-market
Sea transport	Hydrogen derived fuels: methanol, ammonia, synthetic fuels	2030–2040
Air transport	Hydrogen derived fuels: methanol, ammonia, synthetic fuels	2030–2040
Bus transport	Hydrogen: compressed or liquefied	2020–2025
Rail transport	Hydrogen: compressed or liquefied	2025–2030
Heavy goods vehicles	Hydrogen: compressed or liquefied	2025–2030

It should be pointed out that projects are currently underway in the listed transport sectors for the use of hydrogen or its derivatives as zero-emission fuels offering reduced CO_2 emissions.

Which of BGK's business model programmes offers such financing?

Infrastructure, Transport and Logistics

SDG:

Mode of transport		Company	Description
	**Sea transport**	**New Times Shipbuilding** China	In 2022, Chinese shipbuilder New Times Shipbuilding constructed and unveiled a vessel powered by liquefied natural gas (LNG) that is fully adapted to run on ammonia.
	**Air transport**	**Airbus** France	The French aircraft manufacturer wants to start testing a flagship A380 with a modified powertrain capable of running on synthetic fuel by 2026. The Group's goal is to produce a fully zero-emission aircraft in 2035.
	**Bus transport**	**Solaris** Spain	Bus manufacturer Solaris unveiled a new model of the Urbino 18 city bus in September 2022. It runs on a hydrogen-powered fuel cell. The process of refuelling the bus to a full tank will take 15 minutes and the range will be around 350 km.
	**Rail transport**	**PESA** Poland	Polish rail vehicle manufacturer PESA, based in Bydgoszcz, Poland, unveiled its first hydrogen locomotive, named Trako, in 2021. Potential first customers for the new unit will be PKN ORLEN and PKP.
	**Heavy goods vehicles**	**Volvo** Sweden	In 2022, the Swedish company began testing a new line of hydrogen-powered trucks with a claimed range of more than 1,000 km and a refuelling time of less than 15 minutes. Hydrogen-powered trucks are also expected to have the capacity to produce electricity for the purposes of the driver or handling the goods being transported.

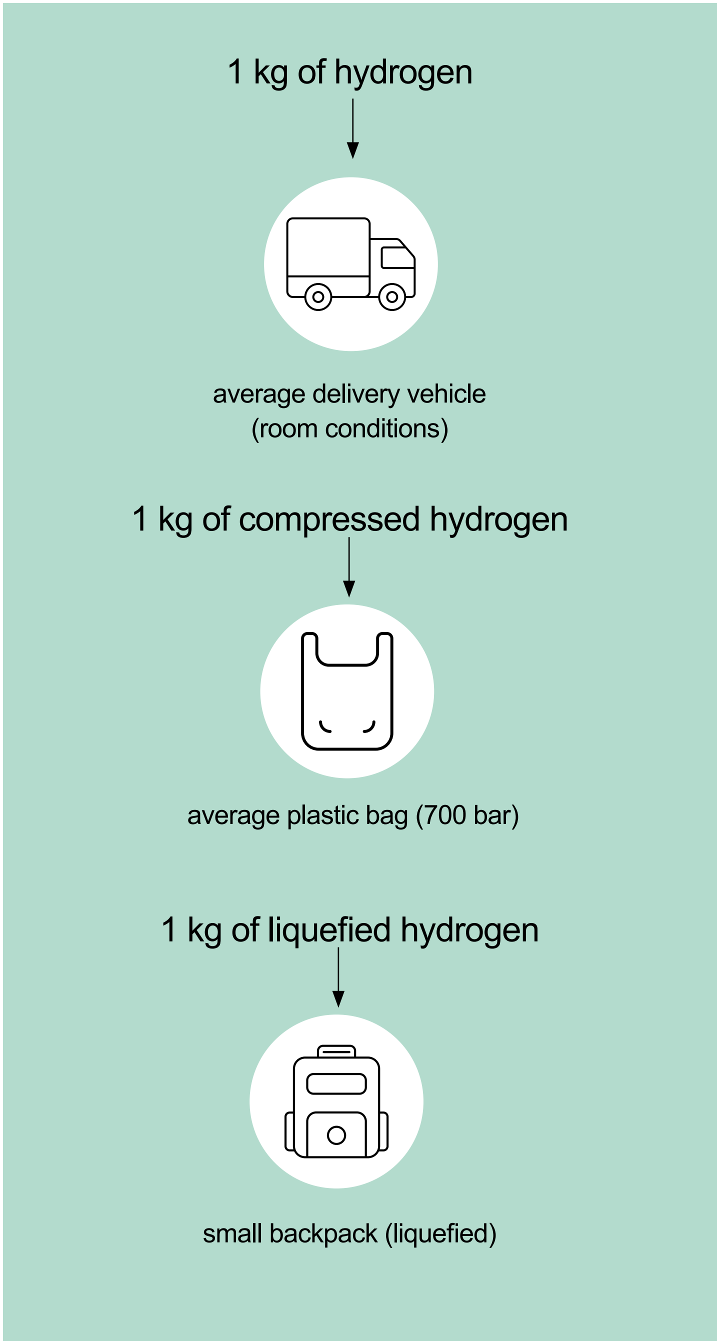
Hydrogen as energy storage: how much electricity fits into a kilogram of hydrogen?

The high energy value of hydrogen, as discussed earlier, can also be exploited in the energy storage sector, the importance of which will be crucial to achieving the energy transition in a way that is safe for the economy as a whole.

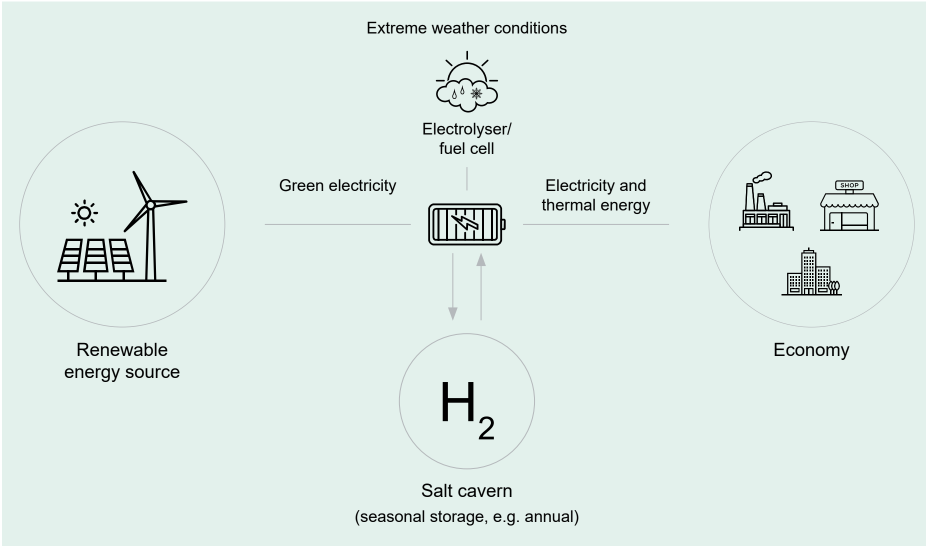
More than 33 kWh of energy can be stored in one kilogram of hydrogen, which is relatively high compared to other energy carriers, such as natural gas. As it allows for the storage of more energy, hydrogen can be used to balance the country's seasonal energy system. In practice, this could involve stabilising a number of renewable energy sources by producing hydrogen to be injected into underground geological structures such as salt caverns.

In such a system, hydrogen would act as a huge energy store, providing an emergency source of energy especially during those times of the year when energy demand exceeds supply. These can be during periods of very hot summers or in sub-zero winter temperatures.

During periods of extreme weather, when the national energy system is overloaded, hydrogen could be converted back into electricity or heat.



Due to the high energy losses in the processes of injecting hydrogen underground when converting it to electricity or heat, hydrogen storage should be done in the long term rather than the short term. Hourly or daily stabilisation of RES sources with hydrogen may not be cost-effective in many cases. In contrast, seasonal balancing of the electricity system using hydrogen may be most effective for large-scale RES sources such as the offshore wind farms currently being built in the Baltic Sea. It is also advantageous that some of the largest underground geological structures capable of storing hydrogen in Poland are also located along the coast of the Polish part of the Baltic Sea, e.g. in Kosakowo.



> Large-scale RES sources such as the offshore wind farms currently being built in the Baltic Sea may be necessary to ensure the production and storage of large quantities of hydrogen.

Which of BGK's business model programmes offers such financing?

Industrial Development | *Infrastructure, Transport and Logistics* | *Strategic Security*

SDG:

Grupa Lotos (now Grupa ORLEN)

Hestor

In 2015, Grupa Lotos carried out the Hestor project to explore the possibility of storing hydrogen in salt caverns located in Poland.

WTT

Power 2 Gas

WTT develops innovative solutions for waste management and energy. Its proprietary ZEWE technology enables the complete elimination of waste while obtaining high-purity hydrogen.

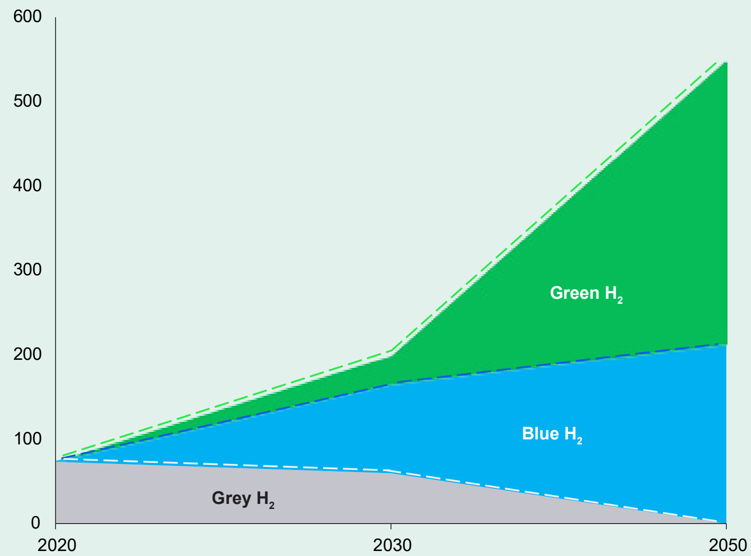
Industry is going to get greener

Globally, 90% of hydrogen for industrial use is produced from natural gas or coal[1].

However, more and more industrial companies around the world are looking to move towards the use of less emissive types of hydrogen, such as blue and green hydrogen. Necessary factors for the development of a greener production of this resource will be the parallel construction of new RES sources, as well as the popularisation of CCS facilities for the capture and storage of carbon dioxide.

The use of blue and green hydrogen in production processes will result in a significant reduction in carbon dioxide emissions compared to the use of grey hydrogen. At the same time, the new types of hydrogen used can ensure that industrial companies remain compliant with current or forthcoming regulations, as well as greater resilience to rising energy costs.

Distribution of hydrogen production in the scenario of achieving net climate neutrality (1.5°) (Mt)



Source: IEA, 2021

Power generation: is hydrogen the oil and gas of the 21st century?

Hydrogen may become the fuel of the future. Above all, it has the potential to supply energy to all sectors of the economy, including industry, housing and transport. The use of green or purple hydrogen will allow for the comprehensive decarbonisation of selected sectors in line with EU climate policy.

Hydrogen has an advantage over oil or gas because its energy density is almost three times higher. Out of 1 kg of hydrogen, a fuel cell is able to produce around 16 kWh of electricity. The properties of hydrogen can be influenced by changing its temperature, pressure or physical state. Hydrogen has a higher energy yield under pressure or in the liquid state than at standard atmospheric temperature and pressure.

Fuel type	MJ/kg
Hydrogen	141.8
Methane	55.5
Ethane	51.9
Propane	50.35
Butane	49.5
Petrol	47.3
Diesel	44.8
Coal	15–27

The use of hydrogen in transport requires a specific approach. Hydrogen has very good properties as a fuel, as it has a high energy density (1 kg of hydrogen has approximately three times the energy content of 1 kg of diesel oil). At the same time, hydrogen has a very low volumetric density (at room pressure and temperature, 1 kg of hydrogen occupies some 11 m3, the volume of an average delivery vehicle). A standard passenger vehicle needs around 1 kg of hydrogen to travel 100 km. This means that the use of hydrogen as a fuel under ambient conditions would require each passenger vehicle to haul a tanker behind it as a tank of fuel. For this reason, hydrogen requires a change of physical state for transport applications. The most common is compression to a level of 350–700 bar or hydrogen liquefaction, which occurs at -253 degrees Celsius. Both of these processes reduce the volumetric density of the hydrogen many times over, meaning that it can be stored in a fuel tank of standard dimensions.

Hydrogen also has great potential in heating. Mixed with natural gas, it can be transported through the gas network and significantly reduce emissions associated with heating homes and buildings. However, this involves prior measures such as replacing installations and using appropriate technology in the dwellings.

Which of BGK's business model programmes offers such financing?

Industrial Development

Infrastructure, Transport and Logistics

Strategic Security

SDG:

H21 Leeds

Great Britain – Northern Gas Networks

Hydrogen gas | Leeds | Can-do Cities

The H21 Leeds City Gate feasibility study showed that gas decarbonisation using hydrogen is technically feasible and cost-effective. This is because burnt hydrogen, unlike natural gas, does not produce CO_2, only heat and water. The use of hydrogen in heating will require the development of transmission and distribution infrastructure.

Enea Ciepło and NCBiR

Poland – Zielone Ciepłownictwo

Enea Ciepło has signed a contract with the National Research and Development Centre (NCBiR) for research and development work on the feasibility of using green hydrogen in district heating. The task of the consortium, which includes a company from the Enea Group, is to develop a concept for powering a gas engine with green hydrogen produced in an electrolyser using electricity derived 100% from RES. The resulting energy is to be used for district heating.

Is the future of carbon black?

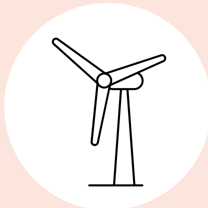
How can carbon revolutionise the world?

Power generation: does only coal as a fuel count?

Due to their diversity and technical performance, elemental carbon-based materials can contribute to the fight against global warming. In particular, nanotechnology may play a large role in halting the rise in global temperatures.

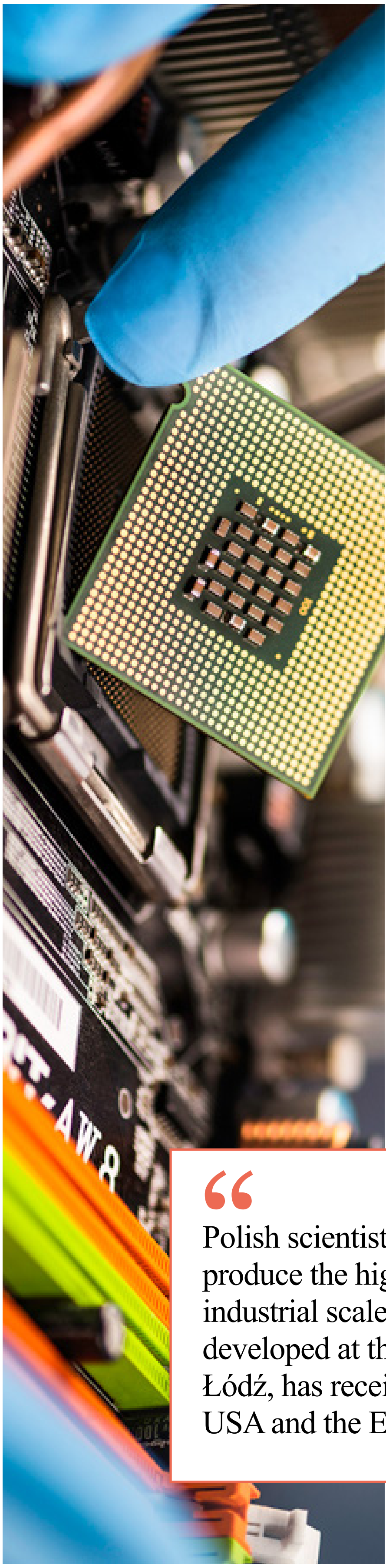
Carbon nanomaterials have unique properties that make their use particularly beneficial in clean energy production technologies. Nanotechnology can reduce the cost of catalysts and membranes used in fuel cells for hydrogen production. In addition, the use of lightweight, more robust nanomaterials for rotor blades can increase the efficiency of wind energy. Their use can also help to reduce the price of photovoltaic cells and, in the case of precision agriculture, optimise the crops used for biogas and biofuel production. That's not all – carbon nanotubes are being successfully used in batteries and supercapacitors, responding to the growing need for energy storage. The use of nanotechnology allows for much better ionic transport and electronic conductivity compared to conventional battery materials, which significantly speeds up charging times and could revolutionise the electromobility industry. Another new development in power transmission infrastructure is the use of carbon nanotubes in electric cables, high-voltage lines or smart grids, which can significantly reduce power losses.

The use of nanomaterials will allow us to produce electricity more efficiently, store and transmit it more effectively and, importantly, avoid energy losses.



The use of carbon fibre in the manufacture of the windmills reduces their basic weight by 20%. This saved 20% of weight allows the length of the blades to be increased without the risk of overloading and consequently increases the amount of energy produced by the windmill.

Li-ion batteries using an ultra-fast carbon electrode can double the amount of stored energy, extending the range of an electric vehicle up to 1,000 km.



Electronics: can carbon replace silicon?

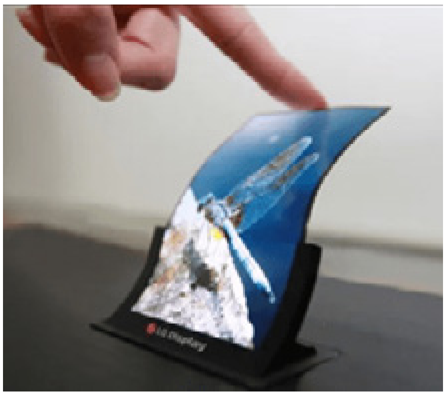
Modern electronics are mainly based on silicon, whose importance in the technological development of mankind can hardly be overestimated. However, new materials are needed to take a ground-breaking step forward.

We are now moving towards miniaturisation in the IT and Telecom industry. Today, electronic equipment designers are operating in a world of transistors whose size is already counted ... in atoms. If we look at the properties of silicon, it soon becomes clear that we are reaching the final frontier in the development of traditional integrated circuits designed using this element. Given such circumstances, many scientists are very much looking forward to the development of nanomaterials, and graphene in particular.

Carbon-based materials can be an alternative to silicon technology, as they have great potential for use in building future generation electronic devices. Their physical, chemical and electrical properties, such as high conductivity, thermal and electrochemical stability and large specific surface area, allow them to meet the requirements of the modern IT industry.
New nanomaterials are also a response to growing market needs with dwindling resources or even deficits. The crisis in the global market for semiconductors – essential components for all kinds of electronics – has made us aware of this.

Carbon-based nanomaterials have great potential in applications such as sensors, semiconductor devices, conductors and smart textiles. Thin layers of carbon nanotubes allow the transition from the rigid architecture of silicon integrated circuits to flexible electronics that allow the freedom to deform the material. It can already be used for the production of flexible screens in mobile phones, and in the future, for example in medicine, to produce sensors that would look like a sticker. Such sensors attached to the skin could monitor the patient’s body temperature and other parameters.

> “Polish scientists have patented a method to produce the highest quality graphene on an industrial scale. Its method of production, developed at the Technical University of Łódź, has received patent protection in the USA and the European Union.

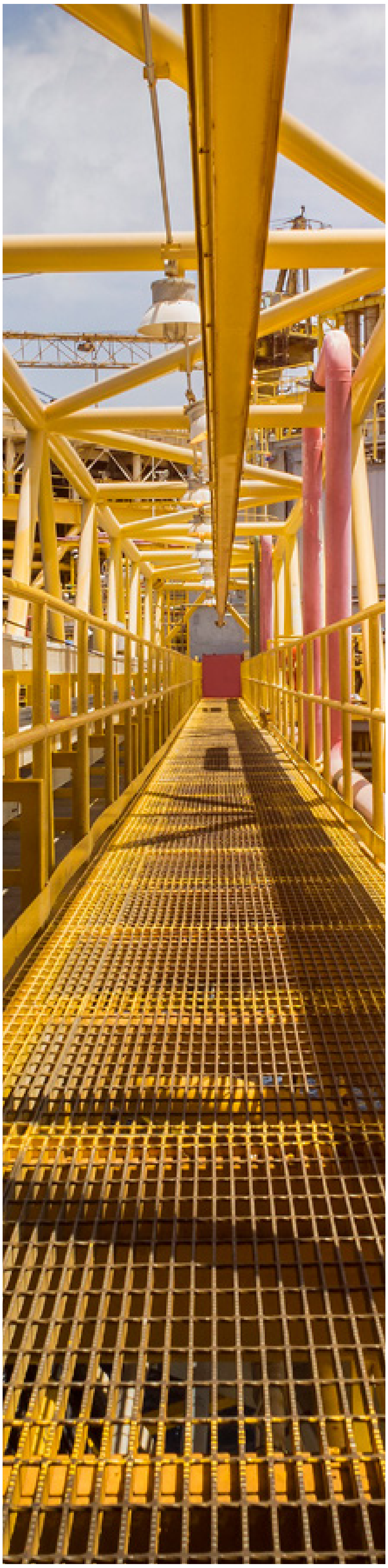


Aerospace and defence: will carbon make aircraft invisible?

Due to the ever-increasing need to produce lighter, stronger and more cost-effective systems, there is a strong demand for advanced carbon materials. Carbon-based materials can be used in many different areas, from lighter, more agile aircraft to new hypersonic systems.

Potential applications for future advanced carbon materials include self-repairing, smart textiles, adaptive plastics and biomimetics (modelled on solutions from the natural world). Scientists in the US have developed a coating of carbon nanotubes that disperses light and radio waves. Coated with it, stealth aircraft would be undetectable by radar. Advanced carbon fibre-based components are used in the industry for their high strength and low weight. This allows cost savings of 20 to 50% by reducing the weight of the aircraft, which significantly reduces fuel consumption. Future uses of carbon nanotubes could also include hydrogen storage, lightning protection for aircraft, mitigating aircraft icing or reducing the weight of airframes/satellites, making them easier to launch into space in the future.

One area of knowledge where nanotechnologies could be of significant economic and environmental importance in the future is tribology. It studies friction, wear and lubrication of moving assemblies of machinery and equipment. Friction processes cause large economic losses due to the consumption of materials and energy. This is why solutions have been sought for years in the field of surface engineering and lubricants to reduce these processes. Adding carbon nanomaterials to lubricants can significantly extend the life of aircraft components.



Construction: will carbon help us reduce the use of concrete?

Concrete is one of the most important materials for the construction industry, but its production places a heavy burden on the environment due to its high carbon footprint.

Carbon-based materials are much more durable and flexible than those traditionally used in construction. For this reason, the incorporation of reinforcements or carbon nanotube particles increases the strength of the concrete by up to 30%, so that much less concrete can be used, which in turn reduces the amount of emissions generated during the production process.

Enriching building materials such as asphalt or concrete with graphene also prevents ice formation. This is due to graphene's ability to raise its temperature under applied tension.

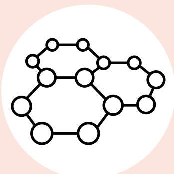
Carbon-based materials are widely used to improve the structural properties of steel, which also plays a key role in construction. The use of carbon nanotubes increases its tensile strength by up to 150 times while reducing its weight by 6 times compared to conventional designs.

The addition of carbon nanoparticles to coatings and paints provides better corrosion and wear resistance, as well as prevents condensation and mould formation. Additionally, it improves their chemical, optical, aesthetic and electrical properties.

The use of graphene and carbon nanomaterials in this industry enables the creation of advanced, multifunctional products that respond to different stimuli, such as temperature changes or mechanical stresses, whereas the presence of carbon nanomaterials in putties and adhesives facilitates repairs and maintenance work. This is due to their ability to self-cure when an electrical charge is applied, without the need for heating.

Concrete and steel are the most popular construction materials of today, but the industry is expected to see a significant increase in demand for smart nanomaterials in the near future.

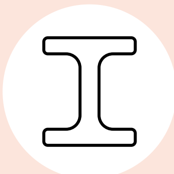
Carbon fibre vs steel



Carbon fibre is **5x stronger** than steel.

Carbon fibre is **2x more rigid** than steel.

Carbon fibre is **5x lighter** than steel.



Medicine: can carbon help diagnose cancer?

Nanomedicine is a branch of medicine that uses the advances of nanotechnology to revolutionise treatment, diagnosis and therapy and the development of new medical products.

Medicine's interest in nanotechnology has been determined by the fact that the particle size is similar to that of antibodies, membrane receptors, nucleic acids, proteins and other biomolecules. These molecules can cross the blood/brain barrier due to their size. The high surface-to-volume ratio of the particles and the ability to modify their properties make them ideal tools for imaging, diagnostics and therapy.

Carbon-based materials also have great potential as drug delivery systems. The most commonly used carriers are carbon nanotubes modified with various types of biological substances. Nanotube surface modification is possible due to the high availability of binding sites for the active substance on the lattice of carbon atoms. They have also become a popular tool in cancer diagnosis and therapy. They are considered one of the most promising materials with the ability to both detect cancer cells and deliver drugs or small therapeutic molecules to cells.

Smart carbon nanomaterials are biomimetic, meaning that they can mimic structures and processes found in living organisms. They can be used as artificial muscles that contract and afterwards return to their original shape.

Carbon fibre is also widely used in the construction of prostheses, making them much stronger, lighter and weatherproof. The use of carbon fibre in prosthetic feet allows for very good dynamics not previously possible.

Which of BGK's business model programmes offers such financing?

Healthcare

SDG: 3 GOOD HEALTH AND WELL-BEING

ENForce Medical

Polish company ENForce Medical Technologies has created the first 100% Polish-made bionic prosthetic foot. The prosthesis allows flexion at the ankle joint within a range that corresponds to the natural one, thus allowing for fluidity and dynamic movement during every step, regardless of the terrain. The use of a carbon fibre composite combined with a lightweight core has resulted in a high-strength, lightweight material. It has the advantage of providing the patient with the right dynamics and freedom of movement. Carbon fibres allow the prosthesis to be matched to the patient's individual expectations, increase mobility and enable the patient to walk longer distances. The carbon fibre foot perfectly simulates "normal" joints, thereby increasing stability and making it easier to maintain balance. It is very comfortable and durable.

The prosthesis allows an ankle joint movement of 20-25°, so no ramp will be a problem for the user. Innovative microprocessor-controlled hydraulics make walking as natural as possible. The prosthesis adapts in real time to the uneven terrain.

ENForce Medical, under funding from the European Regional Development Fund, is developing a prototype of an ultralight and durable knee prosthesis that will allow amputee patients to recover and return to full life activity. As part of the prototype development, the company is also using artificial intelligence to detect gait phases and the system responsible for shin rotation.

Graphene-based sensors are slowly establishing themselves as the basis for the production of modern bionic prostheses.


3

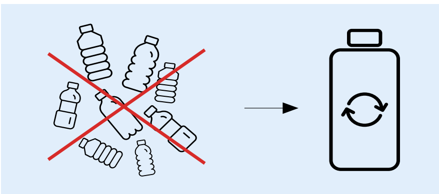
What will the 3W world look like?

Sustainable world

Synergy of 3W resources

A sustainable world is one in which we use the resources we have in the most efficient way, try to reduce their consumption as much as possible and think about the total environmental cost of our actions. Synergies of water, hydrogen and carbon will certainly have applications in technologies of the future, but in certain areas they are already finding them today. These three resources, each of which is of great importance, can do even more for the development of Polish technology if used together.

The most common example of the synergy of 3W resources is the use of activated carbon in the purification of tap water in our homes. Water from municipal intakes is disinfected with chlorine, which is necessary to clean it bacteriologically, but at the same time gives it a specific taste and smell. To get rid of it, we can turn to activated carbon filters, which remove chlorine and other organic pollutants.



Which of BGK's business model programmes offers such financing?

Entrepreneurship Development

Dafi

The essence of the benefit of this synergy has been recognised by the Polish company Dafi, which has been producing activated carbon filter water bottles for years. One filter replaces up to 100 disposable bottles. By using them every day, each of us can build a sustainable 3W world. The synergy of 3W resources is with us in our daily decisions. Well worth appreciating the opportunities that arise from its use.

SDG:

6 CLEAN WATER AND SANITATION

The synergy of 3W resources is also being used in much less common technologies today, as illustrated by the Nanoseen company we referred to in the *Not only tap water* chapter. Polish start-up Nanoseen has created the world's first technology for desalinating and purifying water without energy supply. In the future, their invention could help solve the problem of drinking water shortages in many areas that, although surrounded by seas or oceans, suffer from a lack of potable water.

Which of BGK's business model programmes offers such financing?

Industrial Development

Grapheme

Work on solutions using the presented example of synergy is also going on intensively outside Poland and is appreciated by EU bodies. The French Grapheme project uses chemically adapted graphene and related materials to remove toxic contaminants from water and filter out particles, microorganisms and dissolved solids. This project has received significant financial support from the Horizon 2020 programme[8].

SDG:

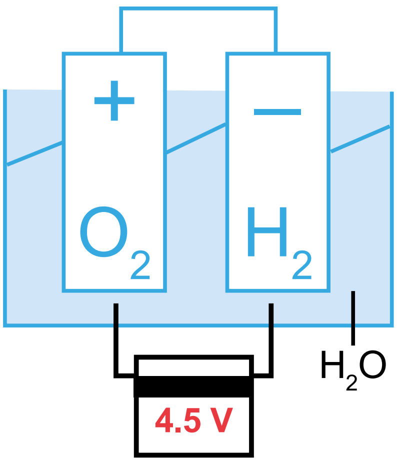
6 CLEAN WATER AND SANITATION

The European Union is looking for innovative projects that will create a sustainable world. In this respect, the 3W synergy can be used particularly often.

8 CORDIS Results of EU-supported research, *Graphene and related materials membranes for efficient removal of toxic cations from water,* https://cordis.europa.eu/project/id/899596/pl (accessed: 09/09/2022).

Use of water in hydrogen production

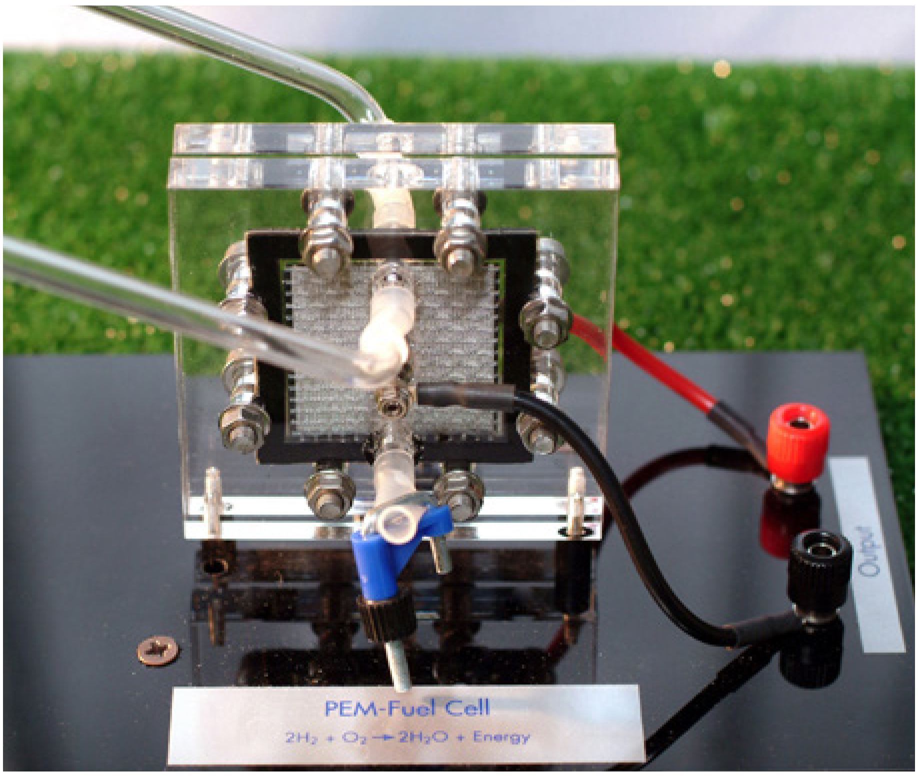
An example of a process involving water, hydrogen and carbon at the same time is the production of green hydrogen by electrolysis with water. This hydrogen can be used to power the bus, which uses a fuel cell built partly from... carbon.



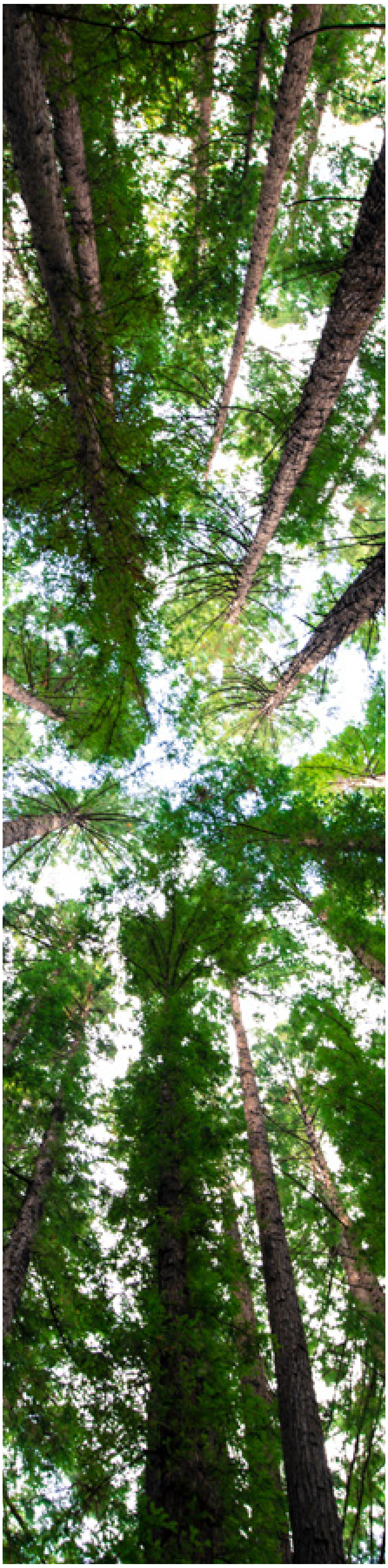
Water is needed to produce green hydrogen, i.e. hydrogen that does not emit CO_2 into the environment. It is the basis of the electrolysis process, during which its molecule is broken down into hydrogen and oxygen when subjected to an electric current. For the reaction to take place, it is necessary to prevent these elements from recombining. A separator placed between the electrodes serves this purpose.

It is usually a porous material saturated with an electrolyte and conducting ions. It allows the reaction to be carried out effectively. The electrolysis of water is an uncomplicated and relatively inexpensive commercial means of obtaining hydrogen and oxygen with very high purity.

The potential to produce hydrogen from water is still being developed. Until now, using salt water for this process has been problematic. The negatively charged chloride in the sea salt causes corrosion of the anode, which enormously shortens the life of the entire system. However, researchers at the University of Central Florida (UCF) have developed an innovative nanomaterial that enables the efficient electrolysis of seawater without releasing any harmful chemicals. The efficiency of seawater electrolysis has the potential which could significantly exceed the results of the process to date. Such technology will also reduce the use of fresh water and therefore help rational water management.



Use of carbon in fuel cell production

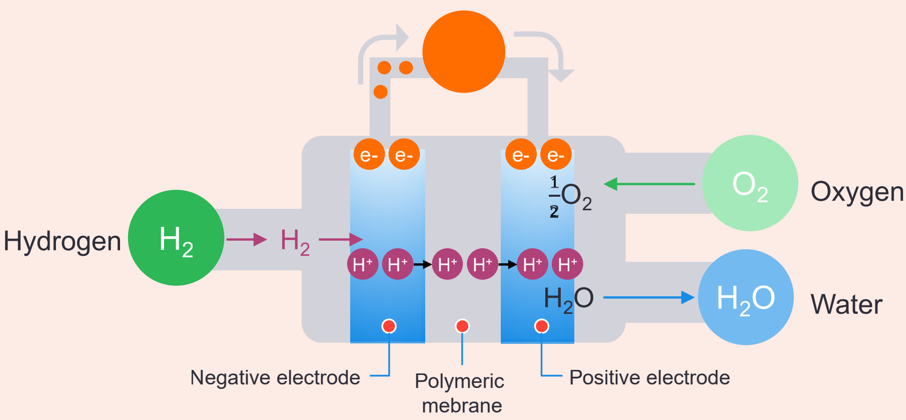


What may seem surprising in many industries, the simultaneous use of carbon is also required to use hydrogen. This happens, for example, in the fuel cell production process, during which non-energetic carbon is used.

Fuel cells are used to generate energy under controlled conditions, in a process in which hydrogen and oxygen react with water to produce electricity and heat without combustion.

Fuel cells are similar in structure to electrolysers, with one of their main components being a membrane constructed using non-energetic carbon derivatives. For this reason, access to low-cost and large-scale production of elemental carbon is essential for their production.

How fuel cells work
Flow of electrons (electricity)



Carbon composite hydrogen storage facilities

A very interesting example of the use of hydrogen and elemental carbon synergy is the production of pressurised and cryogenic vessels in which hydrogen is stored. Such vessels, reinforced with carbon fibre, are currently in production. They are used for stationary as well as mobile hydrogen storage.

Hydrogen-powered vehicles are becoming increasingly popular due to their low or zero emissions. The global market for such vehicles is estimated to have exceeded $1 billion in 2019 and is likely to grow 14-fold by 2026. Carbon fibre-reinforced tank technology is increasingly being used in both passenger and truck transport, as such vessels are much lighter than traditional steel or aluminium tanks. This makes them an important element in the development of low-emission fuel cell-based hydrogen transport. In addition, such tanks can be used in extreme weather conditions, have a longer service life and are much safer than traditional solutions. Thanks to the discussed advantages, the technology is getting increasingly popular.

Such technology is also extremely important for decarbonising heavy transport, which has the greatest difficulty in “going green” due to its long distances and high payload requirements. To improve operational economics, vehicles need to be able to reach long distances and refuel quickly. The heavy weight of the electric batteries would reduce the potential payload and range of the vehicle and require long charging times. For this reason, the ideal solution is to use hydrogen vehicles, using lighter-than-traditional carbon composite tanks that increase transport efficiency when carrying cargo.

Polish start-ups Hydrogen First and Ultralight Green Cylinders are involved in commercialising the concept of large hydrogen pressure vessels built from composite materials. One of the key challenges this technology faces is the high price of carbon fibre.

Humans in the 3W world

3W reality

What will human life be like in the 3W world? Will the 3W Idea affect the quality of life of our society and will it help solve the problems we currently face?

As in the animation entitled "Humans in the 3W world", available on BGK's YouTube channel, the story of the Brown family features 3W technologies making human life simpler and more sustainable.

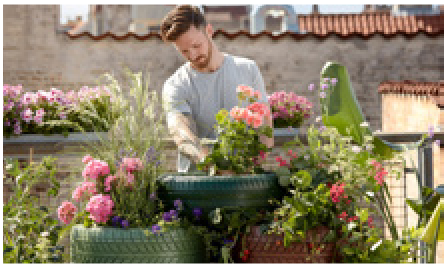
The Brown family have two children and want to leave our planet in the best possible condition for them.

Let's get to know all the family members.

Daughter – Maggie Brown, sportswoman

Maggie kicks off each morning with a running workout with her friend Kate – they are training for a half marathon. Kate lost her leg as a result of a car accident, but thanks to a bionic prosthesis she can easily overtake Maggie. The prosthesis is made of materials that analyse the biosignals that trigger a sensory response, reducing the risk of falling. For training, the girls wear T-shirts with bio-sensors that monitor their vital signs, so they know when their body is under strain. Maggie's smart T-shirt was bought from a military shop. Since she happened to faint during a workout, she always has a bottle with a carbon filter with her, so that she can drink water from the city's intakes without fear. Running is not the only passion Maggie has; after school she goes to tennis training, which she started last year. The racquet she uses is made of nanofibres, and is therefore ultralight, making it easier to manoeuvre and build the right technique. Maggie's favourite way to get home after training is to take the hydrogen bus, because it is so quiet that she can easily review the material before a physics test while on the road. After such an intense day, sleep is very important, so Maggie monitors her sleep parameters with a graphene-based sensor.

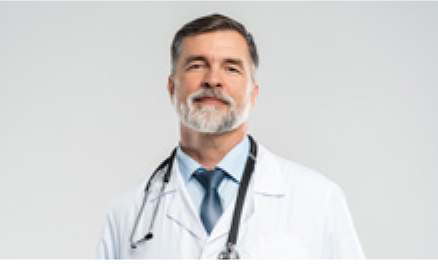
Son – Mark Brown, healthy food enthusiast



Mark, Maggie's brother, supports his sister in developing her sporting career while pursuing his own passions. At home, he is primarily involved in growing fruit and vegetables. Thus, he can consistently provide his sister with the highest quality nutrients. To manage water rationally, Mark installed a home retention system. This allows rainwater to run off directly into the installed underground tank and Mark can use it to water the home garden at any time. The Brown family's retention system has specialist filters and a sensor installed to further purify the water, making it reusable for washing or flushing toilets.

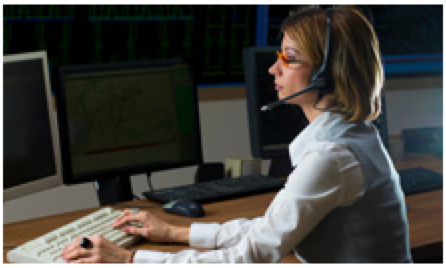
Mark also seeks to promote cutting-edge technology at home that can ensure the family has access to fruit and vegetables even when temperatures outside are unfavourable for gardening. To this end, he decided to install a home aquaponics system in which plants take nutrients directly from the water. In addition, it is combined with the fish and snail culture in the aquarium and the simultaneous purification of the water by adapted bacteria. These bacteria convert aquarium waste into nitrates and nitrites, which promote plant growth. The Browns' aquaponics system allows the family to enjoy organically grown plants all year round.

Father – John Brown, oncologist



John fights for the lives of his patients every day in the Oncology and Haematology Clinic. Thanks to the use of nanomaterials in the diagnosis of cancer, patients are referred to him much earlier, which in many cases makes it possible to beat the disease. Nanoparticles, unlike typical chemical markers, show cancerous changes in the body well and well in advance. Their use when imaging the extent of lesions minimises the need to remove healthy tissue. Nanomaterials also play an important role in patient treatment, as they increase the efficiency of transporting drugs, proteins and DNA into target cells. Their nanoscale size allows them to penetrate cell membranes efficiently and increases their stability, allowing the drug to remain in the bloodstream for longer. During the break, John visits the lab where his colleagues are working on introducing deuterium – a "heavier" isotope of hydrogen - into drug molecules, making them more resistant to breakdown by certain enzymes. The drugs produced by this method last longer and John's patients will be able to take less of them. Working with patients can be very demanding and stressful, so when John returns home he relaxes by playing his favourite arcade games with his family on an interactive multi-touch screen made of nanomaterials.

Mother – Anne Brown, power system dispatcher



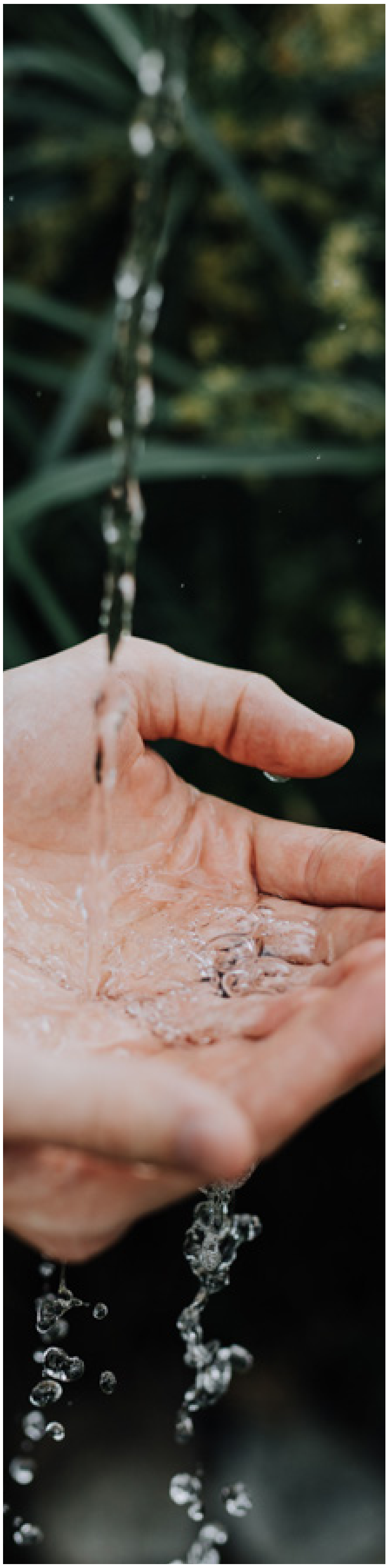
Anne's day job is as a dispatcher at the regional power distribution facility. Her professional duties involve a great deal of responsibility, as she keeps the national electricity grid under constant review so that no part of the country runs out of electricity. Since the domestic electricity sector transformation programme has been implemented, Anne's work has become relatively calm and predictable. Thanks to low-cost photovoltaic panels made from graphene and efficient wind turbines constructed partly from carbon fibre, there is no shortage of electricity anywhere in the country. In the event of unfavourable meteorological conditions, Anne supplements power shortages in the system using energy stores constructed from nanomaterials. During periods of power emergency, such as cold winters or hot summers, Anne activates an emergency power supply using energy stored in underground hydrogen storage facilities. In her day-to-day work, Anne no longer has to face the problem of energy loss, as the country's superconducting transmission and distribution lines made of nanomaterials provide much less electricity loss than in the past. Anne's calm and predictable work is also facilitated by a reliably operating nuclear unit, which is cooled by recycled water and can also be used to produce hydrogen at selected times of the year. Anne finds her work rewarding because she knows that her children will be able to benefit from a zero-carbon electricity system, with hydro, hydrogen and carbon technologies ensuring its high efficiency. After work, her son Mark teaches Anne how plant growth can be stimulated on a large scale with the help of nanomaterials so that in future our electricity system can be further supported by biogas.

Brown's family weekend trip

The Brown family has all the amenities they need in their smart, energy-efficient and self-sufficient home powered by photovoltaics and equipped with a heat pump, energy storage and a gas furnace adapted to burn hydrogen. Nevertheless, on their days off, the family gets out of the house and spends active time on weekend trips. The Browns in particular enjoy exploring different parts of the country. This weekend the family went to a national park to watch wild animals. They could easily get there, as they can get to any other place in the country, in a hydrogen-powered car. The Browns' vehicle is equipped with a hydrogen tank reinforced with carbon fibre, so it has less weight and guarantees greater safety. The vehicle's body was made of green steel fabricated using hydrogen. The Brown family's vehicle releases no emissions, it only produces water. This allows the family to travel without polluting the environment, which is in line with their lifestyle. When they return from a weekend trip they stop at a filling station to refuel their vehicle with hydrogen generated from a local wind farm. Back home, everyone is getting ready for another week of work and study, using rainwater-powered showers and preparing meals from their own fruit and vegetables.

How we build the 3W world

The 3W Idea is to support the implementation of projects in the areas of water, hydrogen and carbon. It was initiated and is being implemented by Bank Gospodarstwa Krajowego based on the premise that the further development of the world, economic growth and the development of innovative technological solutions must not be at the expense of future generations and lead to the depletion of valuable resources.



Therefore, our scenario for the future assumes **sustainable development**, where the need to transform the economy towards zero-carbon is supported by new technologies using the **three resources of life**:

Water, which is the source of life

Hydrogen, which is the fuel of the future

Carbon, which is the material of the future

To this end, we gather and share knowledge to support the implementation of 3W projects. We are also building a community of **talented scientists, courageous entrepreneurs, visionary NGOs** and **responsible public sector representatives** who are interested in maintaining and enhancing our society's quality of life while using less energy and non-renewable resources.

As a Polish development bank, we take on the role of integrator, connecting potential scientific and business partners around these three elements and creating a friendly ecosystem in which new technologies and solutions can develop. We support innovation and the development of research into low- and zero-carbon technologies by assisting scientific institutions, research centres and start-ups through special development programmes based on public-private partnerships. The integration of all actors into one coherent organisational and communication ecosystem offers a huge opportunity to prepare Poland for the coming era of transition towards sustainability and zero-carbon. The potential of the 3W Idea is also based on the development of social capital, as we shape consumer attitudes.

Our project is a unique opportunity to build real strength and enhance Poland's development. Let's explore eight programmes that support the construction and development of the 3W world.

How we build the 3W world?

Eight programmes that can support the development of the 3W Idea.

1 Social and Territorial Cohesion

In today's world, some areas are growing faster and others are stagnating or, worse, experiencing regression. Through the Social and Territorial Cohesion programme, Bank Gospodarstwa Krajowego aims to level the playing field for residents from disadvantaged areas. This programme offers funding (e.g. loans and credits) for investments that will close the gap in development and access to public services in particular areas.

How does the Social and Territorial Cohesion programme link to the 3W Idea?

Local water resource security

Rational management of water resources at the local level requires a strategic approach. Therefore, cooperation between government, business and science is essential in this area. Companies and start-ups are developing technologies for monitoring liquid waste and using technology and IT solutions in the water sector. On the other hand, scientific and research institutions are responsible for creating know-how in water management. Government administration should provide support, dialogue and a local perspective.

New jobs

The use of carbon allotropes offers many opportunities and prospects for the development of new sectors. It is also an opportunity to create new jobs, especially in areas where coal was historically mined. Such areas need support as they are struggling with high unemployment due to the reduction in mining.

2 Infrastructure, Transport and Logistics

The aim of this business programme is primarily to support the expansion of integrated and sustainable road and rail infrastructure. In addition, with its help, BGK supports the development of public transport, contributes to the reduction of vehicle emissions and strengthens the capacity of construction companies or the position of Polish seaports in the Baltic Sea.

How does the Infrastructure, Transport and Logistics programme link to the 3W Idea?

Low- and zero-emission transport

The use of technologies based on innovative applications of 3W resources can significantly accelerate the development of transport and logistics. Electromobility has many limitations that inhibit its global and local potential, such as short range and long vehicle charging times. A breakthrough for electromobility could be the use of carbon nanomaterials, which have the potential to both increase battery capacity and significantly reduce charging times. Hydrogen is fundamental for the development of low-carbon public transport. Hydrogen-powered vehicles are an excellent alternative because, using green hydrogen, they enable emission-free operation and increase the flexibility of vehicle refuelling. This is a very important aspect, especially for public or heavy transport. There is a real chance that by 2030, 60% of the bus fleet in Poland will be hydrogen-powered vehicles. It should be noted that as long as the mains electricity used to charge vehicles or to power an electrolyser that produces hydrogen comes from fossil energy sources, we can hardly talk about a green transition. Underpinning green transport infrastructure is the development of renewable energy sources, for which the 3W resources are also very important.

3 Housing

Through the development of activities under the Housing programme, BGK is primarily seeking to increase the general availability of housing for low- and middle-income people and those experiencing social exclusion. The technical condition of the buildings should be significantly improved and maintenance costs must be in line with the financial possibilities of the residents. In view of rising energy costs, improving the energy efficiency of buildings will be particularly important in this regard. The use of 3W resources can significantly contribute to the achievement of these goals.

How does the Housing programme link to the 3W Idea?

Housing to the rescue of water resources

It is difficult to imagine modernising the housing sector without ensuring proper hygienic and sanitary conditions, which involve supplying high quality water to dwellings.

Buildings should be equipped with systems for rainwater recovery and retention. By collecting rainwater and using it in households, domestic consumption can be significantly reduced. In this respect, it is worth pointing out the activities of AQT Water, which is active in this area in Poland and Europe.

A forward-looking application in housing is the green roof technology described earlier, which allows undeveloped surfaces to be used to improve water retention in urban areas. In housing, it is essential to provide quality resources for residents. We should also bear in mind that, without proper respect for limited quantities of drinking water, it may not be possible to supply it to all those in need in the future.

Clean energy in our homes

The development of hydrogen technologies, particularly those associated with green hydrogen, could in the long term contribute to independence from foreign fossil fuels and a significant reduction in emissions. For the housing sector, it will be particularly important in this respect to provide green energy for residents and thus possibly minimise the problem of smog in cities.

Low-carbon construction

Research shows that the use of graphene in concrete production could lead to a material that is up to 30% stronger than the one currently used. The large-scale application of this solution could also contribute to a significant reduction in emissions in the construction sector.

SDG:

Each of the 3W resources can contribute to the improvement of homes at every stage, from their construction to their use by residents.

4 Strategic Security

We distinguish between energy security and strategic security. When it comes to energy security, we understand it as the certainty of access to key resources both now and for future generations. The shift away from carbon-intensive fossil fuels must be offset by the introduction of new, efficient energy sources. Strategic security, on the other hand, is related to the development of the armaments sector and cyber security. Bank Gospodarstwa Krajowego's ambition is to support efforts to increase both the country's energy security and the growth of defence security, as well as cyber security. The challenges we currently face are Poland's high-carbon energy mix, an inefficient district heating system, an underdeveloped distribution network and the need to move away from Russian raw materials. A significant barrier is the limited funding available for coal users.

How does the Strategic Security programme link to the 3W Idea?

Sustainable energy transition

The use of technologies based on the 3W resources and their synergies is key to achieving the objectives of Strategic Security. Hydrogen produced by electrolysis is called the fuel of the future and has the potential to turn our energy system green. We need renewable energy to produce it, and to develop and diversify renewable energy sources we need... carbon. Not that which we extract as a raw material from underground, but, for example, graphene, which will make it possible to reduce the cost of manufacturing photovoltaic panels or strengthen the structure and extend the life of wind turbines or carbon nanotubes that can reduce losses in energy transmission. Nanomaterials also have the potential to solve the global problem of efficient energy storage.

Defence sector and cyber security

The use of 3W resources does not end with the power industry. Carbon fibre is already widely used in the defence sector due to its high strength and low weight, which helps to significantly reduce fuel consumption.

Carbon composites make it possible to create new materials with very valuable physical and chemical properties. They are used as lightweight and very sturdy structural elements. Coming soon to market are materials developed by creating hydrogen bonds between carbon and Kevlar nanofibres. They will be used to manufacture, for example, bulletproof vests and body armour. Carbon composites have another interesting property: they can be very hard and yet invisible to electromagnetic radiation. This feature is exploited not only by smugglers (diamonds are invisible to border scanners that scan luggage), but also by the manufacturers of armaments. Carbon materials are also used in the development of new types of drones, undetectable by radar.

Nanomaterials also have the potential to improve the country's cyber security by enabling the development of more complex cryptographic schemes.

The role of Bank Gospodarstwa Krajowego is to put forward financial solutions to support measures that improve Poland's strategic security. Dialogue and cooperation between scientific institutions, industry and government is also important, as is international knowledge transfer, which can contribute to the development of smart manufacturing practices and related expertise. All this will reduce the production costs of nanomaterials and composites, which at the moment are the main obstacle to their commercialisation.

5 Industrial Development

Bank Gospodarstwa Krajowego supports the increased competitiveness of Polish industry. Industrial development is particularly important for the sustainable development of the country as a whole, for the creation of local investment networks, and for the creation of new jobs. In this respect, support is directed to national giants and small and medium-sized companies of importance in the light of local development strategies. This support is also available to companies with foreign capital that invest in Poland. A strong focus is put on providing solutions for projects that support industrial development, particularly in the area of implementing new technologies including the Industry 4.0 programme and overseas expansion. By implementing new technologies, businesses can very often reduce their climate emissions.

How does the Industrial Development programme link to the 3W Idea?

Decarbonisation

Decarbonisation of industrial processes will, in many cases, be key to the continued viability of companies. One of the more promising solutions is the substitution of grid electricity by hydrogen-based technologies and, in sectors where hydrogen is already being used, a switch from grey (carbon-intensive) hydrogen to blue and green (low/zero emission) hydrogen. The use of hydrogen, for example in sectors such as oil, fertiliser or steel production, will reduce CO_2 emissions into the atmosphere and thus reduce the costs associated with the rising price of emission allowances of those covered by the EU ETS.

Decarbonisation is also key to achieving long-term climate goals.

Water technologies

Industry has a high demand for water with different quality parameters depending on the sector. In view of the need for responsible management, the development of technologies for the recovery of potable water, as well as the design of waste water treatment and purification plants, is essential. This is a new business area with opportunities to develop know-how and technology, e.g. rainwater and snowmelt management strategies for entire cities or the use of

a weather station to manage reservoir retention. Water technologies also underpin the operation of industrial sectors with a high demand for the availability of water with specific parameters. There are Polish companies engaged in smart water quality monitoring, as well as providing waste water treatment and purification solutions.

Local content developmen

Polish companies, particularly in the SME segment, can ensure the implementation of the 3W Idea with the creation of so-called local content, i.e. the participation of Polish companies in the supply chain for water-, hydrogen- and carbon-related projects.

There are already companies on the Polish market today that manufacture components, assemblies or entire devices in the 3W sectors. A key strategic challenge is to involve these companies in the implementation of ground-breaking projects on a national scale, where they will form an important part of the supplier network. One of the flagship examples of the implementation of the local content development vision is the UK Offshore Wind Sector Deal.

According to figures published by Renewable UK, the share of local suppliers in offshore wind projects in the UK is now 48% and the value of UK wind technology exports was over £ 0.5 billion in 2020. The above experiences can be translated into the development of the 3W market in Poland.

Development of hydrogen production, transport and storage technologies

The development of green hydrogen technology supports decarbonisation. Science and business are working together on new ways to produce, transport, store and use this resource. In Poland, there are innovative examples of the commercialisation of large pressurised hydrogen vessels made of composite materials, the sale of pantograph chargers for battery-powered buses and other solutions, e.g. in district heating. Out of the international examples, it is worth mentioning the British case of enabling hydrogen to be transported via the gas network and used to heat buildings.

Use of carbon-based materials

Carbon-based materials will contribute to the development of new technologies – they are already used in a wide variety of sectors, such as the manufacture of components for electronic devices, the technology industry, the automotive industry, the chemical industry, the energy industry, the semiconductor industry (including LEDs), the medical industry, the construction industry, the pharmaceutical industry and environmental protection. Among other things, these materials are used to increase the rigidity, durability and strength of products. They are perfectly suited to the manufacture of flexible OLED displays based on graphene. They serve to improve drug distribution through graphene nanocarriers. They are contributing to the development of antibacterial materials, bactericidal graphene filaments, and the creation of bionic carbon fibre prostheses.

6 Public Finance

Ensuring the sustainability of public finances through the creation of an efficient public sector banking service system is the aim of this BGK programme. Managing European funds and ensuring the liquidity of funds entrusted to the bank for handling is also important. Although the public finance sector will not be a direct beneficiary of 3W projects, from the perspective of funding opportunities for innovative projects, it has a considerable role in their development.

How does the Public Finance programme link to the 3W Idea?

Regulated support schemes

Water-, hydrogen- and carbon-related projects will have a major impact on creating a decarbonised and sustainable economy in Poland. However, their development, including full commercialisation, may in many cases require state intervention, including from the public finance sector. Regulated support schemes set up for 3W projects can provide key support funding and reduce potential investor risk through the state's role as guarantor. Examples from other sectors, e.g. RES, show that it is with the help of regulated support schemes that innovative projects become able to obtain external funding and consequently their scale of occurrence increases and costs fall. The public finance sector can have a key role in providing funding opportunities for 3W projects. In 2021, Germany received approval from the European Commission to launch a special support scheme for imports of hydrogen and its derivatives called H_2 Global. BGK will work with the public finance sector to develop similar support mechanisms for 3W projects in Poland.

Grants and funding

The public finance sector can also contribute to the development of 3W Idea projects such as non-reimbursable preferential funding schemes or grants. Currently, such programmes are being implemented with the participation of institutions such as the National Fund for Environmental Protection and Water Management and the National Centre for Research and Development (NCBiR). That said, it appears that the current opportunities to obtain funding for innovative energy and environmental projects are not sufficient to deliver the climate transition. Therefore, BGK will, on its own or in cooperation with the public finance sector, work on further developing financial support schemes for energy and environmental projects in the 3W sector, among others.

Redistribution of EU funds

An important role for the public finance sector will also be to ensure that EU funds are properly redistributed and allocated. Projects in the 3W area will be eligible for European funding. In recent years, Polish entities have obtained significant funding from the LIFE fund for the clean-up of Polish rivers, as well as from the Horizon fund for innovative carbon technology projects. Hydrogen technologies can also be funded under EU programmes such as the CEF, Horizon, Innovation, Modernisation or IPCEI programme. The level of use of EU funds by Polish companies is still relatively low. The role of the public finance sector, as well as that of the BGK, should be to educate and support Polish entities as widely as possible in obtaining funds from the European Union.

7 Healthcare

Within the Healthcare programme, BGK's main focus is on improving the quality and accessibility of healthcare. In this respect, measures are being taken to improve the profitability of public hospitals and to invest in the modernisation of healthcare providers. Also of particular importance are systemic and remedial programmes to generate additional resources for essential treatment and projects to ensure the availability of medicines, modern therapies and prevention.

How does the Healthcare programme link to the 3W Idea?

Water quality for hospitals

Hospitals, laboratories and pharmaceutical plants require water with strictly defined parameters to ensure patient safety and protect the equipment used. Hospitals that are provided with quality water treatment and management systems can reduce their water use. Investment in such systems can provide real savings and secure the continuity of the highest quality supply.

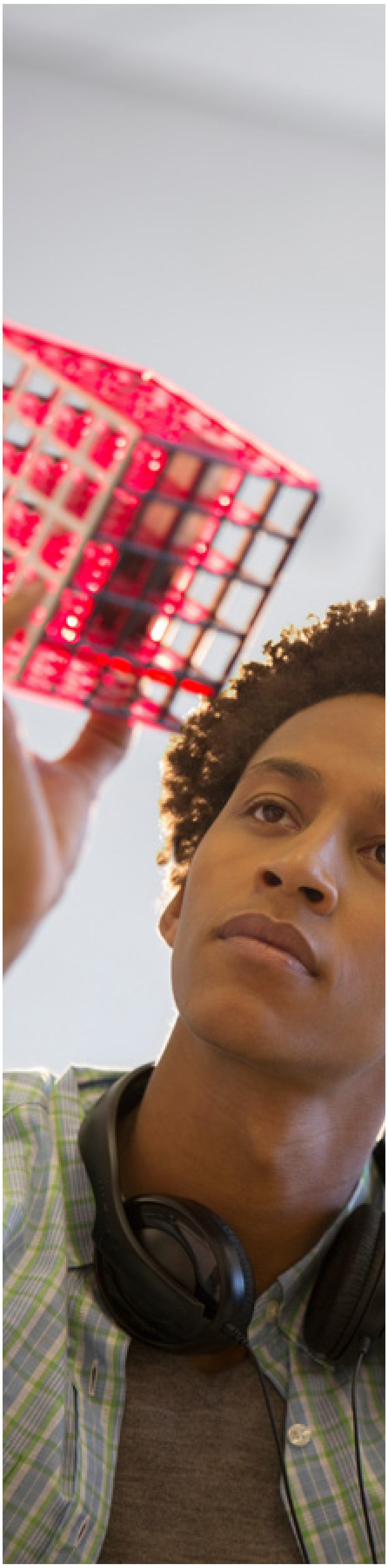
Nanomaterials – bullets in medicine

Carbon nanotubes could become an effective weapon against cancer cells in the future. Research conducted in the European Union shows that carbon nanotubes, when coiled, can accommodate drugs, sensors or heating elements.[9] Through their use, these substances are encapsulated in a protective carbon coating to prevent them from coming into contact with other tissues. In this way, the contents can be safely transported to specific locations in the human body, effectively reaching the cells. At the same time, the remaining tissues are protected from the effects of substances that they do not need.

SDG:

The use of 3W resources can contribute to the effective modernisation of the Polish healthcare sector, increasing innovation and the independence of individual facilities.

9 European Commission, *Carbon nanotubes – bullets in the fight against cancer*, https://cordis.europa.eu/article/id/36049-carbon-nanotubes-bullets-in-the-fight-against-cancer/pl (accessed: 27/09/2022).



8 Entrepreneurship Development

As a state-owned development bank, BGK aims to support Polish entrepreneurs, particularly small and medium-sized companies that design or offer solutions sought by consumers in various sectors. BGK's main objectives in the field of entrepreneurship development are to provide access to finance to as many SMEs as possible, to stimulate investment, especially in the field of digitisation in the business sector, and to educate for entrepreneurship development. By pursuing the objectives of the 3W Idea, BGK wants to provoke action in many areas of the economy by activating the world of business and the world of science. The aim is to harness the enormous potential of Polish entrepreneurs and create a platform for building a modern, innovative and environmentally friendly economy.

How does the Entrepreneurship Development programme link to the 3W Idea?

Connecting large corporations with the SME sector

BGK is pursuing the 3W Idea, developing entrepreneurship in the country. We will seek to aggregate key SMEs in the water, hydrogen and carbon sectors. At the same time, we will be highlighting the opportunity to participate in large business projects once certain conditions are met. Polish SMEs operating in the 3W sectors can be suppliers to large corporations. Combining Polish companies of different sizes in the implementation of 3W projects can secure important economic development for the country, as well as reduce the outflow of capital.

To date, BGK has signed a number of letters of intent with companies from the 3W world, both with representatives from the SME sector including Nanoseen, WTT, Biocent, Nanonet and many others, as well as with large corporations including Toyota.

Knowledge, technology and project transfer

Entrepreneurship development within the framework of the implementation of the 3W Idea will not be able to take place without an appropriate transfer of knowledge, technology and projects between the different market actors. Key activities will be to ensure cooperation between large corporations, the SME sector, research institutions and the financial sector. The programme is also designed to activate the public. BGK wants to be the first player in Poland to ensure optimal management of the process of building Polish local content and national specialisations, particularly in the water, hydrogen and carbon sectors.

List of examples illustrating the applicability of BGK's Business Model Programmes in supporting the 3W Idea

Resource	Business case	Chapter/page	BGK's Business Model Programme
water	Aquaculture systems – Food4Future Technologies	Today / p. 14	Industrial Development
water	Retention system – AQUARes	Tomorrow / p. 24	Housing
water	Desalination technologies – Nanoseen	Not only tap water / p. 34	Entrepreneurship Development
water	Water quality monitoring system – Waterly	Not only tap water / p. 37	Entrepreneurship Development
water	Digitisation system for the liquid waste management – Ścieki Polskie sp. z o. o.	Not only tap water / p. 37	Entrepreneurship Development
water/carbon	Activated carbon filter – Dafi	Sustainable world / p. 61	Entrepreneurship Development
water/carbon	Carbon filter – Grapheme	Sustainable world / p. 61	Industrial Development
hydrogen	Dual-fuel vessel at sea powered by LNG and ammonia – New Times Shipbuilding	Hydrogen: an element for the future / p. 44	Infrastructure, Transport and Logistics
hydrogen	Hydrogen locomotive Trako – PESA	Hydrogen: an element for the future / p. 44	Infrastructure, Transport and Logistics
hydrogen	Hydrogen-powered city bus – Solaris	Hydrogen: an element for the future / p. 44	Infrastructure, Transport and Logistics
hydrogen	Testing of an aircraft powered by hydrogen-based synthetic fuel – Airbus	Hydrogen: an element for the future / p. 44	Infrastructure, Transport and Logistics
hydrogen	Hydrogen-powered truck from Sweden – Volvo	Hydrogen: an element for the future / p. 44	Infrastructure, Transport and Logistics
hydrogen	Hydrogen storage in salt caverns – Lotos (Grupa ORLEN)	Hydrogen: an element for the future / p. 46	Strategic Security, Infrastructure, Transport and Logistics, Industrial Development
hydrogen	Production of hydrogen from waste – WTT	Hydrogen: an element for the future / p. 46	Strategic Security, Infrastructure, Transport and Logistics, Industrial Development
hydrogen	Hydrogen in heating – H21 Leeds	Hydrogen: an element for the future / p. 49	Strategic Security, Infrastructure, Transport and Logistics, Industrial Development
hydrogen	Green heating – Enea and NCBiR	Hydrogen: an element for the future / p. 49	Strategic Security, Infrastructure, Transport and Logistics, Industrial Development
carbon	Production of carbon fibre boats – Rega Yachts	Carbon today / p. 21	Industrial Development
carbon	Production of bionic prostheses from carbon fibre – ENForce Medical	Is the future of carbon black? / p. 56	Healthcare

There is a path from the 3W Idea to the 3W world that may be shorter than we think. Business, academia, government and consumers are following this path together. These people need to have the know-how and tools to be able to create new solutions and technologies. BGK's mission is to create and integrate such a community, so that together we can create a better tomorrow where water, hydrogen and carbon resources are used optimally and sustainably.

3W