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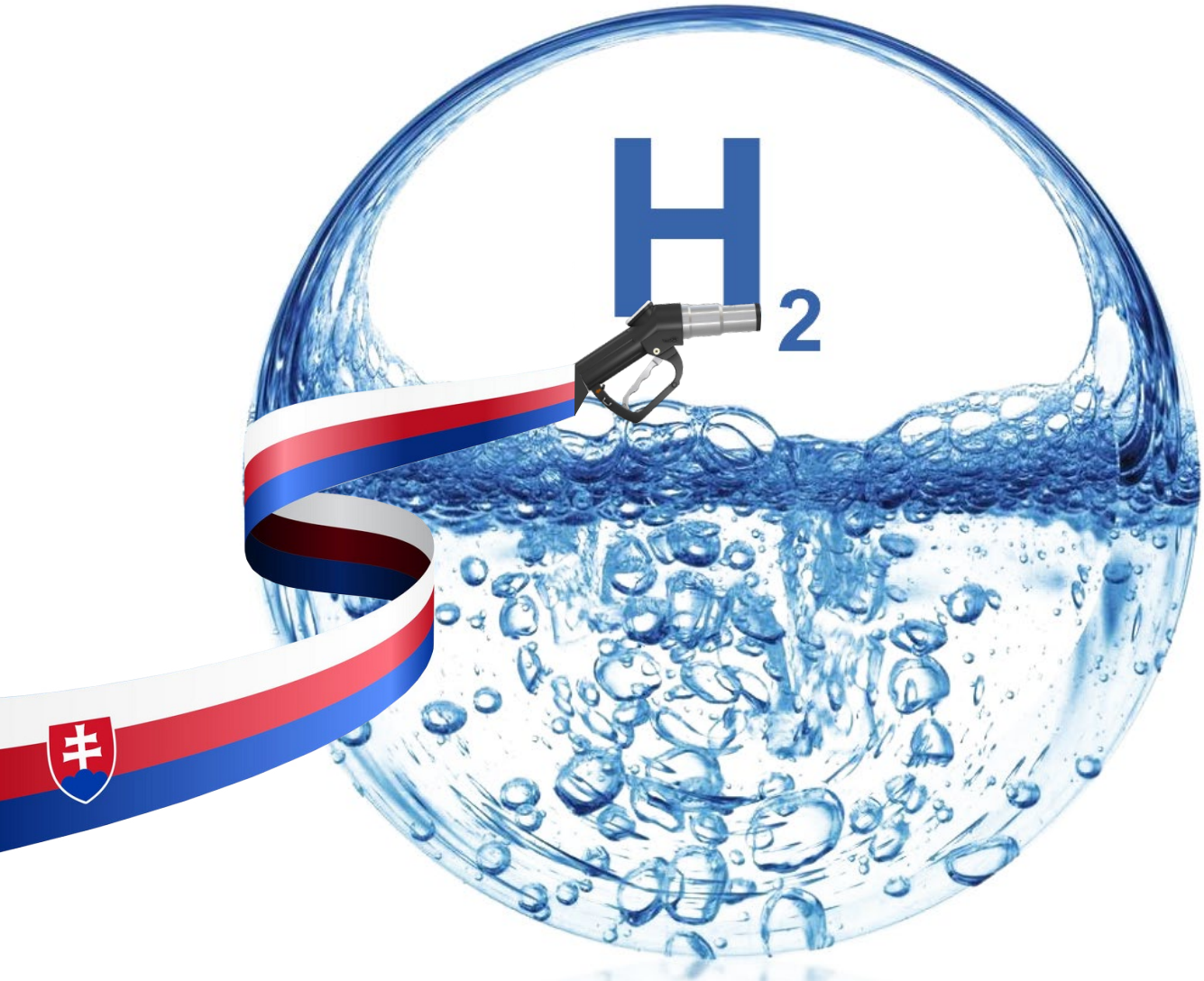
Dr. h. c. mult., prof. Ing. **Juraj Sinay**, DrSc.

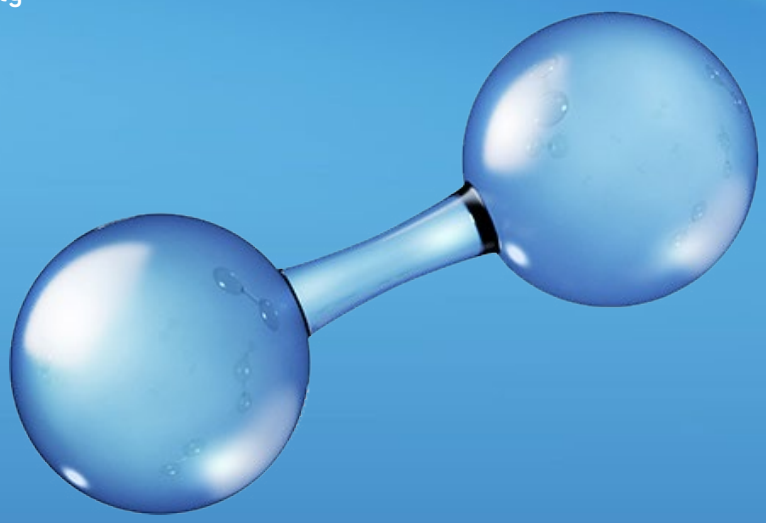
Coordinator of Hydrogen Technologies in the Slovak republic
Technical University in Kosice – Faculty of Mechanical Engineering



National Hydrogen Strategy

We are prepared for the future

Content



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Editor-in-Chief: Dr.h.c. mult. prof. PhDr. Ing. Štefan KASSAY, DrSc.

Reviewer and editor: Dr.h.c. mult. prof. Ing. Štefan Luby, DrSc.

Translated by: RNDr. Jozef Stašák, PhD.

Graphic design: Dušan Ščepka.

The author is responsible for the professional content of the materials.

Dr. h. c. mult. prof. Ing. Juraj SINAY DrSc.

*1949
Bratislava

Is a Slovak Mechanical Engineering expert. He was graduated at Slovak Technical University in 1973 the title associated professor achieved at Berg University in Wuppertal (GFR) in 1990 and he became a university professor in 1991 at Technical University in Košice in a branch of transport and manipulation technology. He deals with problems of technical device safety, dynamics of machines, risk management and technical diagnostics of machines. He is the author and co-author of seven monographs, while three of them have been issued in abroad and more than 300 scientific articles. He was a leader of Security and Production Quality Department within Faculty of Mechanical Engineering in Košice between 2002 and 2019 and he was a leader and supervisor of 28 PhD thesis as well. He acted at university as a vice-dean and vice-rector responsible for external and foreign relations and he was the Slovak Rectors Conference Chairman (2002 – 2005) too. He was the President of Automobile Industry Union in the Slovak republic. Since 2015, he is the Vice-President of Society for Security Sciences in Köhln am Rhein (GFR) and since 2021 he is co-ordinator responsible for hydrogen technologies in the Slovak republic, based on governmental delegation. He was awarded by more honorary doctorates at University of Miskolc, Wuppertal, Užgorod and Ostrava. However, he was awarded by (GFR President Cross, the first level) as well and he is a member of European of sciences and arts in Salzburg too. He was awarded by National Quality Price in the Slovak republic, and he was awarded by silver Olympic rings by Slovak Olympic Committee as well.

Abstrakt

Využitie vodíka je jedným zo strategických nástrojov na dosiahnutie cieľov definovaných v Zelenej dohode pre Európu. Z hľadiska využívania vodíka je dôležité aby sa postupne realizoval prechod zo sivého vodíka využívaného v súčasnej dobe na zelený, príp. modrý vodík. Vedecký výskum a technologický pokrok naznačujú, že využitie vodíka ako efektívneho nosiča energie ponúka perspektívu vzniku nového trhového segmentu. Uplatnia sa v ňom inovatívne poznatky, ktoré v podobe riešení ponúknu odpoveď na prichádzajúce výzvy v priemysle, energetike a doprave. Vypracovaním Národnej vodíkovej stratégie s výstižným prívlastkom „Pripravení pre budúcnosť" a jej schválením vo Vláde Slovenskej republiky 23. júna 2021 sa stala Slovenská republika súčasťou vodíkovej komunity v rámci Európskej únie. Stratégia definuje podmienky pre nasadenie vodíkových technológií v súlade s dlhodobým strategickým zámerom rozvoja SR do roku 2030, resp. 2050. Realizáciou a implementovaním Národnej vodíkovej stratégie „Pripravení na budúcnosť" do praxe prostredníctvom akčného plánu sa vytvoria podmienky pre dekarbonizáciu hospodárstva a energetiky, priemyselných procesov, dopravy a mobility.

Vodík

Emisie

Dekarbonizácia

Národná vodíková stratégia

Mobilita

Abstract

The use of hydrogen is one of the strategic tools for achieving the goals defined in the Green Agreement for Europe. From this aspect it is important that the transition from the currently used gray hydrogen to green or blue hydrogen is gradually implemented. Scientific research and technical progress suggest that the use of hydrogen as an efficient energy carrier offers the prospect of a new market segment. It will apply innovative knowledge that will provide solutions to the challenges of industry, energy and transport. With the elaboration of the National Hydrogen Strategy with the apt adjective „Prepared for the Future" and its approval by the Government of the Slovak Republic on June 23, 2021, the Slovak Republic became part of the hydrogen community within the European Union. The strategy defines the conditions for the deployment of hydrogen technologies in accordance with the long-term strategic development plan of the Slovak Republic until 2030 and 2050, respectively. The implementation of the National Hydrogen Strategy „Prepared for the Future" into practice through an action plan will create the conditions for the decarbonization of the economy and energy, industrial processes, transport and mobility.

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Hydrogen

Emissions

Decarbonization

National Hydrogen Strategy

Mobility

Hydrogen – energy medium for the future

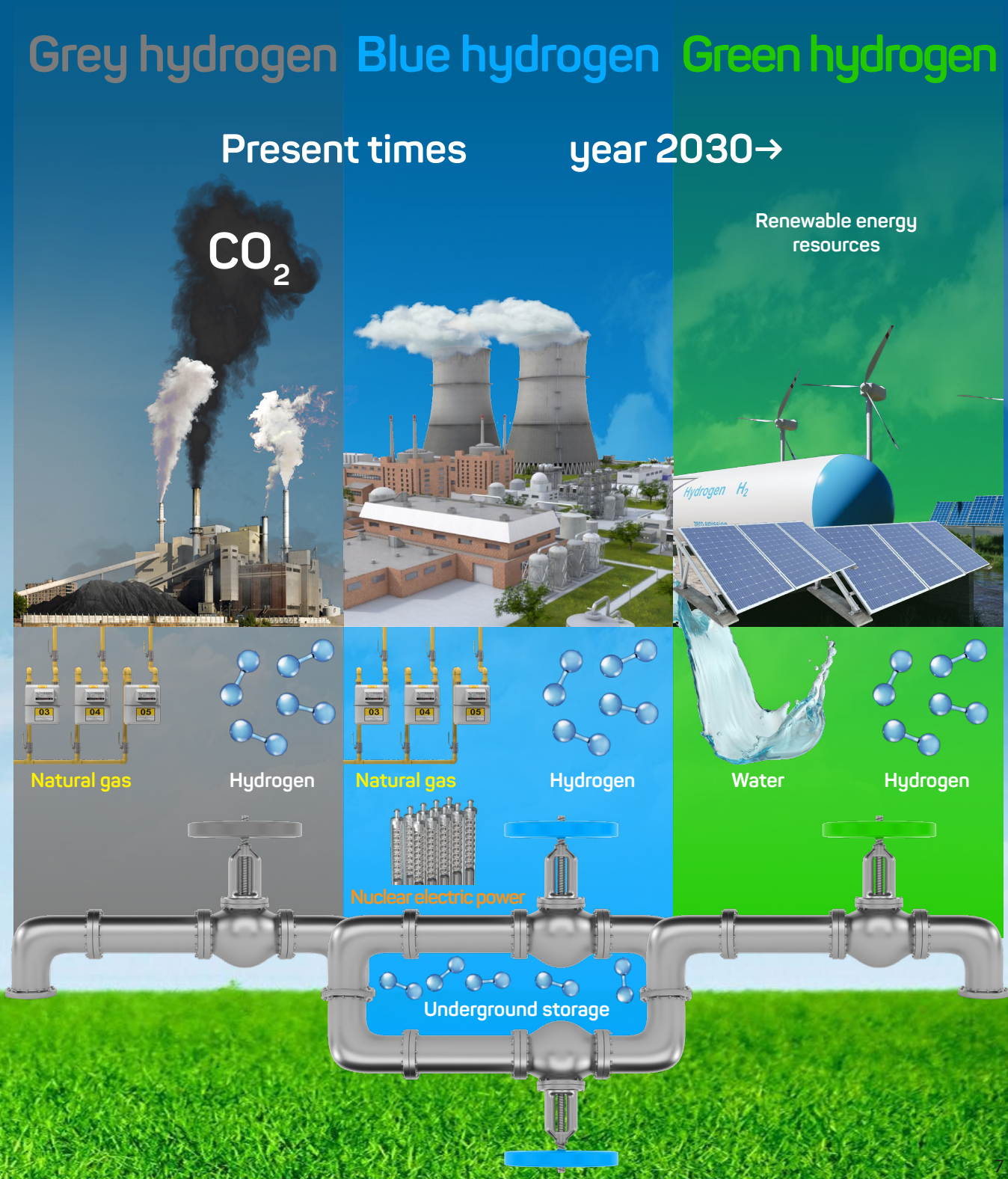
Energy efficiency and renewable resources seem to be inevitable related to successful energy (power) transformation, while in the latest year, there is, observed a remarkable progress. However, there is a need to pay attention to those energy resources and carriers, which do not generate carbon dioxide emissions as well, while the renewable energy resources play a role of principle importance, and a hydrogen utilization seems to be one of the most suitable solutions. On the other hand, hydrogen seems to be one of strategic tools to achieve the goals postulated in the European Green Deal [1].

Obviously, hydrogen might be replaced instead fossil fuels represented by coal, natural gas, methane, etc. However, it might be applied in the chemical industry (ammonia, methanol, and plastic material production), oil cleaning and further processing and metallurgy (in produced steel further processing), where coke can be replaced by hydrogen as well, while transport seems to be a significant business area, where hydrogen could also be applied when providing transfer of heavy loads via roads, rails, water, and air. Of course, in the near future, hydrogen might be applied when driving cars for longer distances especially and the EU goal is to provide utilization of hydrogen, while maintaining suitable conditions from economy point of view.

However, a transition form so called grey hydrogen to green or blue one plays a role of principle importance at present as well, while the way of electric power production applied within hydrogen production plays a significant role, when defining criteria for hydrogen assignment to those aspect groups (see also Fig.1). On one hand, a set of renewable energy resources (wind and solar or living mass) seems to be important, when producing green hydrogen, on the other hand blue hydrogen production requires energy resources, which generate a lowered coal dioxide ratio (electrolysers or nuclear power systems), while the Slovak republic respects both of the above-mentioned approaches.

Hydrogen became a strategy element and seemed to be an efficient energy carrier, while it application within industrial practice creates conditions for lowering of emissions via application of different technologies or production, which enable producing lowered or no ratio of emissions. However, the hydrogen technologies and products produced with the use of them might be active contribution to economy development within appropriate states or countries as well, with respect to maintainable development related to Paris Convention, the aim of which is to achieve a carbon neutrality society up to 2050.

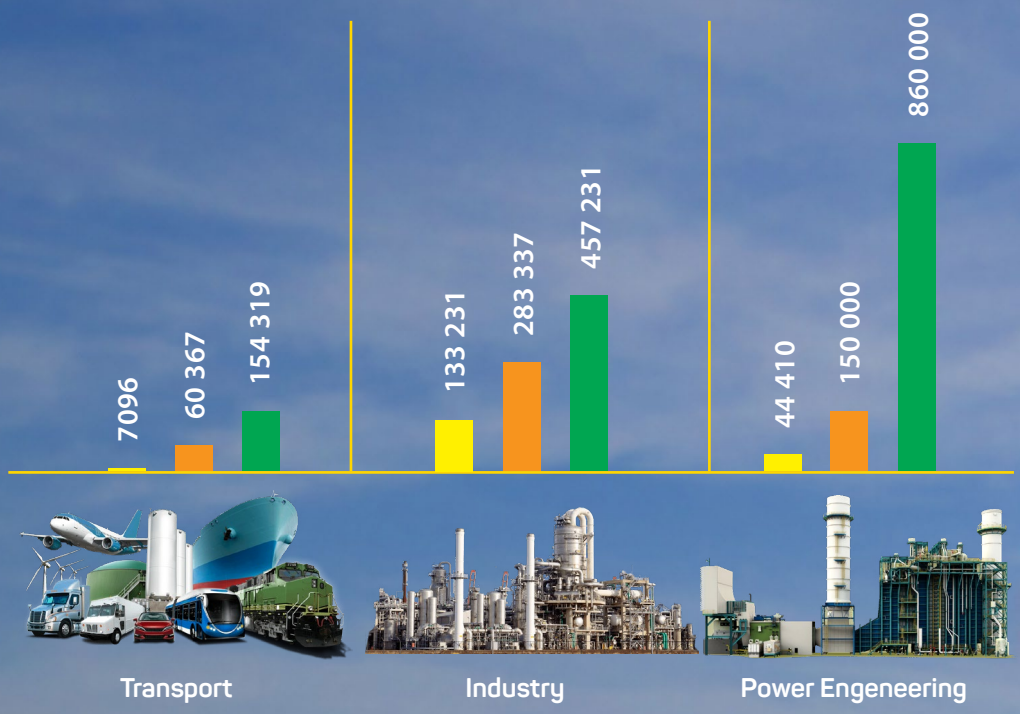
Fig.1 Hydrogen types related to applied energy for its production



On the other hand, there are related to industrial processes, technical and logistic possibilities, hydrogen infrastructure development and other undefined areas at present, which play a role of principle importance, when considering production, storage, transfer, and application of green hydrogen for energy creation purposes as well.

A high ratio of industrial production seems to be a long-term and important integral part of economy performance in the Slovak republic. The multinational firms and companies played a significant role at the beginning of industrial area transformation in the Slovak republic; however, it is important from strategic point of view a new development period to be oriented to firms and companies, which produce products based on domestic development and production as well. However, an industrial sector closely related hydrogen application, which appears in economy, will enable an efficient development of specialized energy mechanical engineering, energy and power systems, chemical and metallurgical industry within mobility areas as well, while those areas include lorry or track production and development of road or rail transportation too. In the future, the hydrogen technology application might be expected in a great deal, especially in the production of light and utility cars, which creates basis of economy in the Slovak republic, and offers possibilities to apply new domestic solutions as well. A consumption of hydrogen will increase up to 2050, as indicate data within relevant firm and companies in the Slovak republic, see also Fig.2 [2].

Fig.2 Hydrogen consumption in the Slovak republic in tones with respect to industrial areas. Years: ▪ 2030 ▪ 2040 ▪ 2050



The partial achievements and results concerned with hydrogen application and utilization within economic space of the Slovak republic and Europe, an intensity related to scientific research and innovation application within that area created a set of conditions for preparing of strategic material, which define a position of hydrogen technologies in the society of the Slovak republic. However, the Slovak republic became an integral part of EU Hydrogen Community and was connected to significant lands, which define their energy future with respect to Paris Agreement, where hydrogen utilization plays a role of principal importance as well, while it could be achieved based on National Hydrogen Strategy with attribute "Prepared for the future", which had been prepared and approved by the Slovak Republic Government, on June 23, 2021 [3].

A scientific research and a technological progress indicate that a hydrogen utilization as ana efficient energy carrier offers a creation of a new market segment, where innovative knowledge should offer an answer related to coming challenges concerned with energy and transportation systems in form of appropriate solutions. However, the industrial, research and development capacities and resources should be aimed to product and technology creation, which generate export potential as well, while that approach seems to be a concrete contribution relate to economy of the Slovak republic.

The National Hydrogen Strategy of the Slovak Republic

The strategic meaning of hydrogen utilization is defined in the National Hydrogen Strategy of the Slovak Republic (hereinafter known as NVS Strategy) related to the neutral Europe from climatic point of view approved July 8, 2020 [4]. This action enabled interconnecting of the Slovak republic to such countries as the Czech Republic, Germany, Sweden, Nederland, France, and Italy, where the Hydrogen Strategy was or will be approved and accepted. However, the NVS Strategy should create conditions which enable the Slovak republic to become the land, which will actively contribute to fulfilment of Paris Agreement provisions as well, while an appropriate Action Plan with defined procedures leading should enable achieving pre-defined goals and aims defined within above-mentioned strategies too. On the other hand, the NVS Strategy has been prepared based on Hydrogen Strategy related to neutral Europe from climatic point of view. However, its compatibility with the GFR National Strategy played a role o f principal importance, while the economic relations between SR and GFR seem to be developed very well [5].

The following goals and aims should be achieved based on the prepared and approved NVS Strategy:

- To contribute to decarbonization with the use of green hydrogen produced based on renewable energy resources. However, there will be applied blue hydrogen as well, while it will be produced with respect to the procedure shown in Fig. 1 too.
- To create conditions for intensive development of hydrogen technologies within all phases related to hydrogen chain, it means production, distribution, storage, and utilization (see also Fig.3).
- To increase a competitive capability of the Slovak industry via adequate support of research and development.
- To prepare capacities for production of energy with the use of renewable energy resources.

Hydrogen in transport

Fig. 3 The complex hydrogen chain

1 **Electrolysis** – Electric current water splitting, while hydrogen and oxygen is being generated

2 **Solar hydrogen generation** – Solar energy application for water splitting with the use of thermochemical operations

Transport and storage

3 **Pipe** – Hydrogen transport via new or modified gas networks

4 **Underground gas storages** – The season hydrogen requirements will be compensated via underground hydrogen stores

5 **Tanks** – Hydrogen distribution via road networks

6 **Filling station** – Hydrogen delivery for mobile purposes (cars, trucks, buses, trains, ships)

7 **Ships** – Green hydrogen delivery with the use of ships within existing water transport ways

Utilization areas

8 **Buildings** – Hydrogen utilization for production of heat and electric energy (power) I buildings

9 **Industry** – Hydrogen for generation of heat and electric energy applied within production technologies

10 **Power station** – Electric power production with the use of hydrogen, which plays a role of fuel and with the use of waste heat as well

11 **Refinery** – Production of hydrogen synthetic fuels

12 **Public transport** – Motorcars driven by hydrogen applied for public transport

13 **Bike** – Bikes - driven by hydrogen

14 **Car** – Fuel elements – car and truck driving technology

15 **Truck** – Heavy trucks driven by hydrogen

16 **Ship** – Hydrogen as a fuel for river ship transport

17 **Plain** – Hydrogen as a fuel for river airplane transport

18 **Train** – Trains with hydrogen fuel elements moving on rails without electric power

19 **Skyrocket** – Hydrogen as a rocket fuel

To prepare conditions for green hydrogen import based on resources in abroad. The NVS Strategy defines a set of conditions related to setting of hydrogen technologies with respect to long-term strategic development intension of the Slovak republic up to 2030 or 2050 respectively. On the other hand, the 55 percent lowering of greenhouse gases in EU is expected to 2030. However, an appropriate co-operation with EU and other countries in the world in hydrogen technology implementation is expected as well and the entire Slovak republic is interested in hydrogen utilization too. The Slovak Republic Government, state and private firms and companies, research, development, education, and territory governmental institutions should be sharing at hydrogen implementation with respect to NVS Strategy Action plan.

National Hydrogen Strategy Structure

Part A Preamble, outgoing Points, Hydrogen Mission of climatically neutral European union

The first part of the above-mentioned strategy defines hydrogen features, which plays a role of energy source and carrier. However, that strategy defines a set of possibilities related to hydrogen utilization within various economic areas as well, while it defines different hydrogen types with respect to NVS Strategy valid in Germany too. On the other hand, that strategy interconnection with climatically neutral European Union is observed as well, while the strategy outgoing points are represented by max. 470 billion Euros investments for green hydrogen and 18 billion investments for blue hydrogen applied up to 2050. However, there is an assumption that green hydrogen will create 24 percent of energy requirement in 2050 as well.

Part B – Hydrogen utilization

In the NVS Strategy, there are also postulated reasons, why the hydrogen utilization might change the economy of energy in the Slovak republic (SR) and to contribute to decarboniza-tion of society, while there is stressed a need to apply removable energy resources, when pro-ducing hydrogen with the use of electrolysers too. However, the Slovak Government declares support related to green hydrogen production as well, while the same is doing concerned with blue hydrogen product within temporary period too. The above-mentioned support also is concerned with research, development and innovations and education form preparation of experts who deal with hydrogen technology problems, while there is emphasised support for Slovak firms and companies, which create an integral part of hydrogen consortiums in abroad, via creation of clusters, scientific parks, and common business subjects.

A utilization of hydrogen in the chemical industry is postulated within **Section B.1.** There will be supported activities, which prefer generation of energy needed for hydrogen production based on renewable resources or nuclear power systems and not based on fossil fuels at all, while the chemical industry seems to be the greatest hydrogen producer and consumer in the Slovak republic as well. A need of metallurgical industry change, so that a consumption of grey hydrogen is lowering and could be replaced by green or blue hydrogen, because that industrial area also generates considerable quantities of coal dioxide within Slovak republic. When comparing it with steel production in the world, the CO_2 generation is at about 7 percent, in the Slovak republic that item achieves 13,9 percent [6].

There should be paid attention to innovative logistic solutions concerned with hydrogen storage, transport, and distribution, when considering gas industry. The actions needed for support of those activities are being postulated in **B.3 Section**, while the hydrogen production with the use of high temperature pyrolysis and gasification of wastes, which cannot be recycled is supported in a great deal. The hydrogen utilization within heat economy is postulated within **B.4 Section**. A quantification of efficient ratio concerned with replacement of natural gas by hydrogen will be a subject of qualified analysis provided by experts who deal with those branches and preparing appropriate building projects.

However, the hydrogen utilization is closely related to adequate transport operations, when considering the social attitudes as well, while those aspects are postulated within **B.5 Section** and the hydrogen most frequent application within driving systems of mobile facilities is implemented via fuel elements, which offer new opportunities in a market (see also Fig.4).

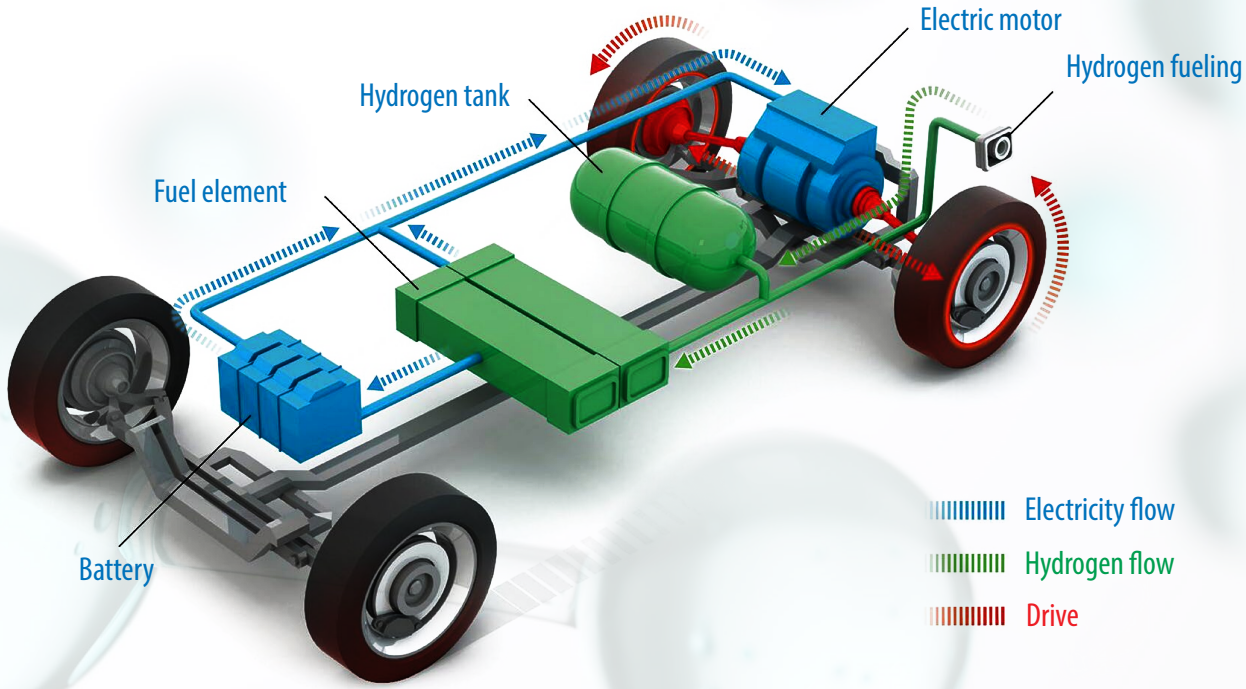


Fig.4 A hydrogen drive principle based on car example

The fuel elements might be applied within different transport facility categories, while there might be considered cars and trucks, buses, locomotives, manipulation mobile facilities applied in building industry, forest economy and internal transport within firms and companies. On the other hand, there should be built an appropriate infrastructure for hydrogen supply. This is postulated within NVS Strategy as one of the steps supported by Slovak government at present. An intensive application of hydrogen drives for the future, which create an integral part of the complex hydrogen chains is shown in Fig.5. An implementation of the above-mentioned interconnections creates a lot of opportunities for Slovak investors and Slovak industry and enables sharing at production of components within entire hydrogen technological chain and creating new workplaces, while this is a great contribution to Slovak industry maintenance too. It is important to have a qualified estimate related to hydrogen consumption to determine an appropriate support for green hydrogen production, while the **NVS Strategy (Part 6)** defines adequate volumes up to 2030, it means 185 kilotons per year, while the supposed growth up to 2050 is estimated to 1473 kilotons per yea and the entire hydrogen production share should achieve 90 percent of all low coal energy resources (see also Fig.2).

Part C – Transformation of industry in the Slovak republic

However, the NVS Strategy includes a need of change in the industry, the aim of which is to contribute to national economy decarbonization as well, while it determines goals, which correspond to energy and climatic plan of the Slovak republic for period 2021 and 2030. With respect to that need the strategy defines that hydrogen technologies represent one of possibilities, which enables providing changes in the industry to maintain an adequate competitive capability. Simultaneously, the strategy postulates that a hydrogen production increasing with the use of renewable resources and technologies should correspond to needs of final or end users.

When considering those aspects, there should be defined a need related to looking for a set of possibilities concerned with electrolysers and to develop a production of metal hydride containers or vessels, while it will be a great challenge for the industry of Slovak republic. However, an appropriate support of device construction, which enables producing renewable resources energy needed for hydrogen production in an appropriate quantity will play a role principal importance as well.

Hydrogen in transport

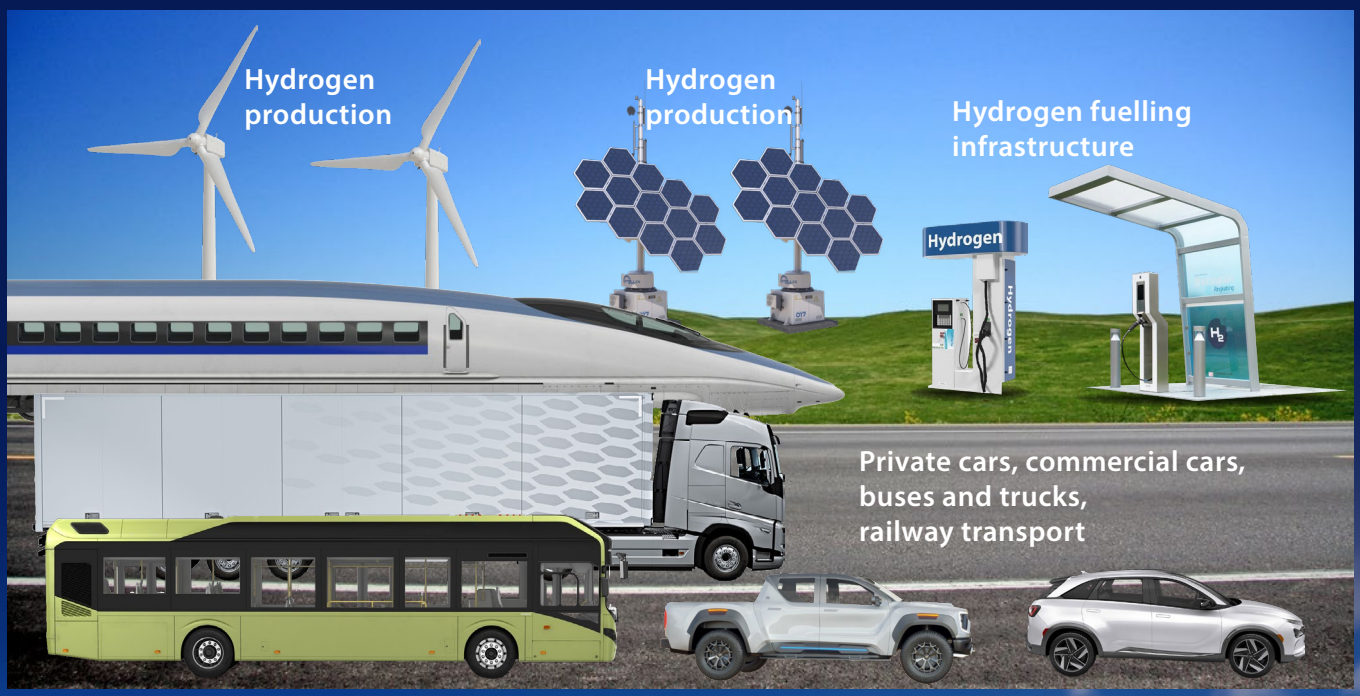


Fig.5 Hydrogen utilization in transport – logistics system [7].

Part D – Governmental Measures

The NVS Strategy document generates a possibility for the Government of the Slovak republic to create a coherent framework for hydrogen utilization within entire chain related to hydrogen production, storage, transport, and distribution together with production of adequate products. However, a creation of conditions for policy implementation related to preparation of supporting schemas, the aim of which is a decarbonization of the Slovak society, creates an integral part of that strategy as well. The strategy creates basis for support of science and innovation, which seems to be a facility for maintenance of the Slovak economy. On the other hand, an appropriate legal framework implementation with respect to EU land compatibility plays a significant role too.

Finally, a set of appropriate financial frameworks related to implementation of hydrogen technologies into social and industrial area of the Slovak republic will be prepared too. There will be respected the EU project schemas based on accepted conclusions, which define the Europe as a leader for utilization of green hydrogen. Furthermore, the NVS Strategy provides summarization of financial mechanisms for support of hydrogen applications, where the support based on state financial plan might be done as well, while a Renovation and resistant plan for the Slovak republic plays a role of significant financial source of the above-mentioned activities too. The strategy postulates a set of possibilities related to creation of public and private partnerships concerned with financing widespread infrastructure projects, while a risk capital for the beginning firms and research institutions, might represents one of such possibilities as well.

Part E – Research and Development Tasks

Hydrogen technology research and development activities will correspond to implementation of Strategy related to intelligent specialisation for the Slovak republic RIS3 and EU policies, while there will be paid attention to those key pilot scientific and research projects, which support all the areas concerned with hydrogen chain. On the other hand, appropriate changes will be manifested, first of all for those regions where grey hydrogen is applied at present, while there might be postulated regions of Nitra, Košice, Bratislava and Šaľa, Finally, the financial support for creation of partnerships related to hydrogen application applied research will play a role of principal importance as well, while there might be involved scientific parks of Slovak universities, Slovak Academy of Sciences and other research institutions and they will be allowed to create an integral part of different international consortiums and there will be possible a cooperation among domestic and abroad firms and companies tool.

However, there will be established the Hydrogen Research Centre in Košice (hereinafter known as the CWVT Center, the aim of which is a concentration of disponible capacities providing basic and applied research concerned with hydrogen technologies. Simultaneously, the CWVT Centre will be an open institution operating within all areas of the Slovak republic and that institution partners will be institutions providing research and development activities concerned with hydrogen technologies from SR and from abroad too.

Finally, that centre will be providing coordination and consulting activities, when preparing ne studying programs concerned with hydrogen utilization as well. The CWVT Center funding will be assured based on diversified financial resources within Frauenhoffer Society in GFR. On the other hand, there will be supported hydrogen technology start-ups, while the NVS Strategy document contains examples of several projects concerned with basic research and innovation activities, where the intellectual property protection for all scientific and innovative teams will play a role of principal importance too.

Hydrogen Technology Safety

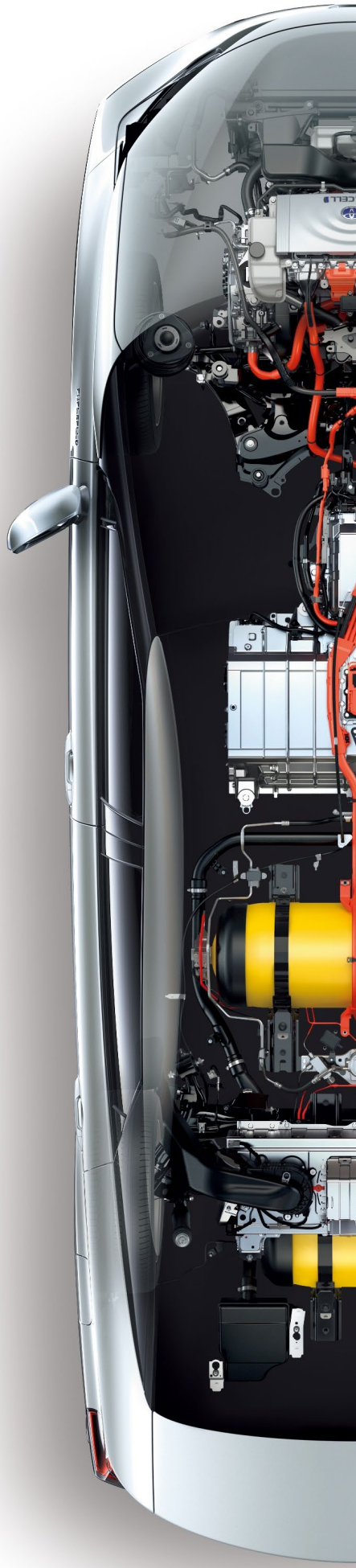
The prevention principal rule is to avoid a creation of hydrogen and air mixture, when manipulating with hydrogen, while that mixture is explosive in a great deal and there is an increased accident risk, while any spark or flame source, e.g., open flame, spark, cigarette, electrostatic discharge, or any heated subject, might cause an explosion of that mixture. At any places, where a hydrogen manipulation is provided a strict safety and firefighting rule keeping is strictly required. When looking at history, we might remember an accident of Hindenburg airship caused by creation of hydrogen and air mixture near the airship fuel unit and the similar accidents occurred in cosmonautics, where hydrogen plays a role of an efficient fuel for spaceship driving mechanisms [8].

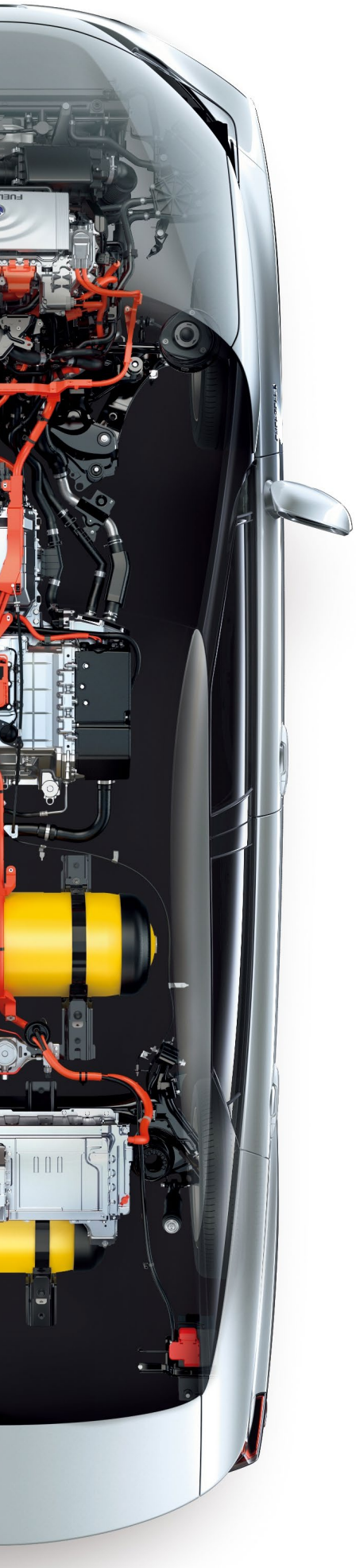
However, a risk minimization, when manipulating with hydrogen within transport facilities seems to be one of strategy areas as well. A detailed analysis of risks is postulated in material [9], while there are defined risks in all areas of hydrogen manipulation chain related to transport means and facilities (see also Fig.5).

However, there is considered with a hydrogen transfer to filling stations, fuelling process, operation of private car, trucks, trains, to achieve and busses being operated with the use of hydrogen, while transport in tunnels, underground garages, closed garages, which create an integral part of houses, bus terminals, etc., plays a role of principle importance from this point of view too.

In the near future, hydrogen will be applied for drive of plains and ships, where the research activities are achieving a high standard and level and many materials exist, where the procedures closely related to risk management are described [10], which represent an outgoing basis for definition of final aims related to avoiding accidents, when applying hydrogen technologies within all areas of economy existing in highly developed countries.

However, there will not be any possibly to achieve an adequate competitive capability of hydrogen technology, without appropriate risk management, when comparing them with conventional technologies applied within all areas of industry and transport as well, while that risk management meaning is postulated in the NVS Strategy document (see also Part D and Appendix no.3a too. On the other hand, in area of basic research, there is proposed, that the risk management problems also should create an integral part of all projects supported by EU actual financial schemas and financial schemas valid in the future.





Conclusion

The fact concerned with glasshouse crop lowering about 55 percent up to 2030, when comparting it with 1990, represents an obligation for Slovak republic, which seems to be a matter of principle importance. However, the Slovak republic postulated the obligation to achieve decarbonization up to 2050 as well, while hydrogen application as an energy carrier within entire value chain seems to an important factor. At the beginning of the above-mentioned value chain is standing the hydrogen production, transport, distribution, storage, and its utilization within final technologies, products and components might be found at that value chain end, while the NVS strategy postulates the strategic task of the state (country), when applying hydrogen strategies in the Slovak republic with respect to actual development within other EU countries too. The aim of that material is to increase the Slovak republic economy competitive capability, with respect to Paris Agreement, which i the SR signed too, while that strategy defines conditions related to hydrogen technology implementation according to Integrated National Energetic Plan /INECP/ [10].

The NVS Strategy – Prepared for the Future implementation via Action plan will enable creatin the conditions for decarbonization of Slovak economy, power engineering, industrial processes, transport, and mobility as well, while that strategy enabled to SR to become a member of EU countries, which created a governmental framework for achievement climatically neutral society to 2050 too.

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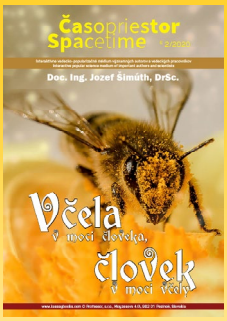

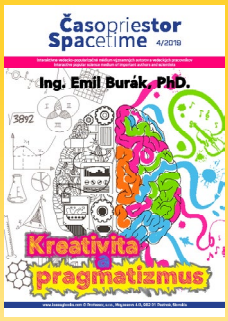

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