The 1st Renewable Hydrogen Energy Conference (RH2EC-2021)

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Book of Abstracts

Ankica Kovač
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PREFACE

The highlight of the RHE2C-2021 is the overall recent progress of hydrogen technology including hydrogen production, storage, infrastructure, and its utilization. This comes followed by a discussion on national hydrogen energy strategies, codes, public acceptance, national legislations, regulations, and directives for its introduction on a global level. To reduce CO_2 emissions, and to keep global warming below 2 degrees Celsius, we need to focus on clean energy, i.e., RES in all sectors. Due to their intermittency, RES comes in conjunction with energy carrier and energy storage, and this is (apart from clean transport) where hydrogen takes its major role as the CO_2-free energy carrier that can enable the efficient energy transition.

The aim of RH2EC is to bring experts from industry (energy, ICT, transportation, and all other sectors), scientific institutions, decision-makers, and investors all together with aim of constructive discussion on the sector's decarbonization and efficient regional energy transition.

RH2EC-2021 TOPICS INCLUDE, BUT ARE NOT LIMITED TO, THE FOLLOWING:

- Countries Hydrogen Strategies, Policies, and Roadmaps
- Electrolyzers
- Fuel Cells
- Green Hydrogen
- Hydrogen Stationary Application
- Hydrogen Economy
- Hydrogen in Climate Change Adaptation
- Hydrogen in Energy Transition
- Hydrogen in Smart Grids
- Hydrogen Infrastructure (HRS)
- Hydrogen Management
- Hydrogen on Islands
- Hydrogen Production
- Hydrogen Safety
- Hydrogen Storage
- Hydrogen Technology and ICT
- Hydrogen Technology and AI
- Hydrogen Transportation
- Hydrogen Tourism
- Hydrogen Utilization
- Hydrogen Vehicles
- Hydrogen based Industrial Development
- Life Cycle Assessment of Hydrogen Technology
- Novel Hydrogen Energy Processes and Technologies
- Renewable Energy Sources (solar, wind, hydro, geothermal, etc.)

Assoc. Prof. Ankica Kovač, Ph.D.
RH2EC-2021 Conference Founder and Chair

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PLENARY SPEAKERS

The RH2EC-2021 Organizing Committee expresses gratitude to the plenary speakers who greatly contributed to the conference program:

Dr. Laurent Antoni

Presentation title: EUROPEAN RESEARCH ACTIVITIES ON HYDROGEN AND FUEL CELLS, CONSIDERING THE NEXT FRAMEWORK PROGRAMME HORIZON EUROPE AND THE CLEAN HYDROGEN JOINT UNDERTAKING

Dr. Laurent Antoni is Public Affairs manager for hydrogen technologies at CEA Liten. Laurent Antoni is also since 2016 President of Hydrogen Europe Research, the European research association on hydrogen and fuel cells gathering more than 90 universities and research institutes, member of the Governing Board of the European Fuel Cells and Hydrogen Joint Undertaking (FCH 2 JU).

Prof. Ibrahim Dincer

Presentation title: THE ROLE OF CLEAN HYDROGEN AND HYDROGEN FUELS IN NEAR FUTURE

Ibrahim Dincer is a full professor of Mechanical Engineering at Ontario Tech. University. Renowned for his pioneering works in the area of sustainable energy technologies he has authored/co-authored many books and book chapters, along with many refereed journal and conference papers. Dr. Dincer has chaired many national and international conferences, symposia, workshops and technical meetings. Dr. Dincer has delivered many keynotes and invited lectures. Dr. Dincer is an active member of various international scientific organizations and societies, and serves as editor-in-chief, associate editor, regional editor, and editorial board member on various prestigious international journals. Dr. Dincer served as Vice President for Strategy in International Association for Hydrogen Energy (IAHE) and Vice-President for World Society of Sustainable Energy Technologies (WSSET) for many years. Dr. Dincer chaired a technical group in ASHRAE, named Exergy Analysis for Sustainable Buildings. Dr. Dincer currently serves as President for Hydrogen Technologies Association in Turkey and Chair for Energy Working Group in Turkish Academy of Sciences.

Abstracts

The 1st Renewable Hydrogen Energy Conference (RH2EC-2021)

:: Paper No: RH2EC-2021-1 ::

APPLICATION OF MAGNETIC FIELD IN GREEN HYDROGEN PRODUCTION

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One of the main ways to increase the economic viability of hydrogen technologies, perhaps the biggest obstacle to theirs wider affirmation in the world, is to increase the efficiency of its processes, such as water electrolysis. In this work, the experimental laboratory alkaline electrolyzer was built and tested including and excluding magnetic field between two electrodes. The non-homogeneous magnetic field was created by a pair of neodymium magnets with the magnetic flux on the surface of the magnets of approximately 0,6 T. Effect of the magnetic field on the liquid electrolyte and consequently gases bubbles motion was observed and analyzed. Energy efficiency with and without application of the magnetic field was compared. The application of the magnetic field inside the experimental set-up showed an increase in hydrogen production energy efficiency by approximately 2%.

:: Paper No: RH2EC-2021-2 ::

HYDROGEN EVOLUTION REACTION ON PT NANOPARTICLES SUPPORTED ON TITANIUM OXYNITRIDE

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A scenario in which hydrogen is the main energy carrier would be beneficial from several aspects, including environmental, social and economic. A sustainable way to produce hydrogen is water electrolysis, in which hydrogen evolution reaction (HER) occurs as the cathodic process. Pt nanoparticles supported on high area carbon materials as a state-of-the-art catalyst ensure fast HER kinetics in acid media. One possible way to additionally improve the activity of Pt-based catalysts is to develop an alternative support material capable to induce strong metal-support interaction (SMSI). One interesting candidate is titanium oxynitride (TiONx), which was already been reported as a support for Ir nanoparticles that exhibit excellent oxygen evolution performance. In this work, HER was investigated on Pt nanoparticles supported on TiONx which was finely distributed over graphene oxide nanoribbons support. In comparison with a commercial Pt/C catalyst, higher HER activity in acid media was obtained. We believe that strong metal-support interaction (SMSI) between TiONx support and Pt particles appropriately tunes the hydrogen adsorption energy on Pt and thus accelerates HER.

:: Paper No: RH2EC-2021-3 :

MATLAB/SIMULINK SIMULATION OF LOW-PRESSURE PEM ELECTROLYZER STACK

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Utilizing renewable energy sources for hydrogen production represents a key step forward in achieving a climate-neutral society by 2050. Its efficient production is necessary to be able to compete with the fossil fuel market, whose reserves are slowly running out. The efficient way to produce hydrogen is with water electrolysis using a PEM electrolyzer. For the given electrolyzer, a mathematical model was derived whose purpose is to better describe and predict the behavior of the system and its output parameters with a brief overview of some of the assumptions introduced is given to simplify the model. The influence of these assumptions on the overall error in the mathematical model is also described. A simulation was made using MATLAB/Simulink software to calculate and plot the desired output parameters and compare these results with the data obtained from several manufacturers. To make the simulation as flexible as possible, the possibility of changing the functional simulation parameters was introduced. This allows more diverse results and diagrams, as well as a better understanding of system behavior and the detection of potential calculation errors.

:: Paper No: RH2EC-2021-4 ::

ONE-DIMENSIONAL MODEL OF A MEMBRANE REACTOR PROVIDING HYDROGEN PRODUCTION FROM REFORMATE GAS

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In the present time, the interest in the production of clean hydrogen has increased due to the depletion of fossil fuels and the increase in energy demand. Hydrogen is produced from natural gas through thermochemical processes, especially steam-methane reforming using conventional reactors. Compared to traditional reactors that consist of a steam-methane reformer, two water-gas shift reactors, and a purification unit, membrane reactors provide both hydrogen production and hydrogen separation in the same device. In this study, the one-dimensional mathematical model of a membrane reactor allowing the hydrogen production from methane is solved using MATLAB program. The distribution of the molar flow rates for each species is investigated through the reactor length. In addition, the change in the performance of the membrane reactor (hydrogen recovery and methane conversion) is investigated through the reactor length. The validation of this model is realized with another study in the literature.

:: Paper No: RH2EC-2021-5 ::

STUDY AND ANALYSIS THE PERFORMANCE OF AN INTEGRATED SOLAR COMBINED CYCLE POWER PLANT

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Concentrating solar thermal system (CSP) have recently introduced as solar technologies that used for electrical power generation by heating a working fluid to high operating temperature (>300 ^{o}C) and combining it with a thermodynamic power cycle. The performance of integrated solar combined cycle (ISCC) are analysed and compared with reference combined cycle in this study. Detailed models of the proposed cycles were developed in Microsoft excel environment to evaluate the cycle's performance. The results show that the power of steam bottoming cycle is increased to about 23 MW by solar, that is about 9 % of total power of ISCC at the central hours of the day on the summer. The annual solar share of electrical energy is approximately 68.7 GWh and annual reduction in CO_2 emission are approximately 25417 tons.

:: Paper No: RH2EC-2021-6 ::

HYBRID PEMFC/LITHIUM-ION BATTERY PROPULSION SYSTEMS FOR ZERO-EMISSION RO-PAX FERRIES IN CROATIA: A MULTI-OBJECTIVE OPTIMIZATION APPROACH

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The need to reduce pollutants and greenhouse gases emission due to marine propulsion is important for touristic areas as Croatia, where several ferries operate short and frequent routes in coastal areas. Hydrogen-fueled Polymer Electrolyte Membrane Fuel Cells (PEMFC) are a promising propulsion technology for reducing local emissions. By implementing the computational tool developed in the ongoing research, the present study proposes a multi-objective approach to determine the optimal design and operation in terms of costs (capital and operative) and PEMFC performance degradation for three Croatian ferries, with installed power ranging from 500 kW to 1.2 MW. The typical auxiliary and propulsion power demand of each vessel is assumed to be fulfilled by a hybrid PEMFC/lithium-ion battery powertrain. The results show that up to 13 tonCO2/day, 213 kgNOx/day, and 11 kgSOx/day could be saved with respect to traditional propulsion systems fueled by marine gas oil. The preliminary sizing of the 500 kW ferry report a FC installed power of 400 kW and about 300 kWh battery, and 600 kW and 760 kWh for the 1.2 MW ferry. The proposed multi-objective optimization strategy allows reducing PEMFC degradation by up to about 75%, limiting the increase in daily cost to about 5%.

:: Paper No: RH2EC-2021-7 ::

THE IMPACT OF PROTON EXCHANGE MEMBRANE FUEL CELL DURABILITY ON LIFE CYCLE ASSESSMENT MODELLING AND ENVIRONMENTAL IMPACTS

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Due to the key degradation processes, which takes place in membrane electrode assembly (MEA), proton exchange membrane fuel cell (PEMFC) efficiency can drop significantly. The novel approach presented in the paper is experimental validation of the accelerate stress tests (AST) of low temperature PEMFC that enabled us to set up the semi-empirical model, which was integrated into life cycle inventory (LCI) for operational phase of PEMFC. The option of setting the operating regime to stationary or dynamic was included. The comparison of the results from LCA using the existing secondary LCI and the new novel LCI show that the operating regime and degradation have astrong influence on environmental impacts of the PEMFC system. For the Global Warming Potential (GWP), in the case of "green" hydrogen from wind, the CO_2 emissions per 1 kWh increase by 63% in the case of dynamic operation and by 16% in the case of stationary operation, due to the degradation. For hydrogen from PV power plant, the increase of GWP is 14% in case of dynamic and 6% for stationary mode of operation of 1 kW PEMFC system.

:: Paper No: RH2EC-2021-8 ::

CASE STUDY ON SPATIAL OCCUPANCY ASSESSMENT OF HYDROGEN REFUELING STATION IN CROATIA

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In this paper, a preliminary analysis of hydrogen refueling station (HRS) building possibilities within one existing wind farm in Croatia and its spatial occupancy has been done, as an example and guideline for a further and more detailed techno-economic assessment of HRS feasibility. In order to align with the main goals of today's global energy policy, i.e. decarbonization of worldwide transport, only the production of hydrogen by electrolysis of water using electrical energy from renewable energy sources has been considered within the proposed analysis. In the future work, the economic aspect of the HRS configurations considered here will be further explored depending on the HRS operating characteristics and its components, with the ultimate goal of estimating the price of hydrogen, considering the capital and operational costs.

:: Paper No: RH2EC-2021-9 ::

HYDROGEN REFUELING STATION: OVERVIEW ON THE TECHNOLOGICAL STATUS AND RESEARCH ENHANCEMENT

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Hydrogen refueling stations are key infrastructures rapidly spreading out to support the deployment of fuel cell electric vehicles for several mobility purposes: two- and three-wheelers, light-duty, and heavy-duty mobility. The research interest in these energy systems is increasing, focusing on different research branches: research on innovation on equipment and technology, proposal and development of station layout, and research aiming to provide experimental data sets for performance investigation. The present manuscript aims to present an overview of the most recent literature on hydrogen stations, by presenting the technological status of the system at the global level, and their research enhancement on the involved components and processes. After the review of the mentioned aspects, the paper will present the already existing layouts and the potential configurations of such infrastructures, considering the several options of the delivery routes, the end-user destination, and hydrogen storage thermodynamic status, if liquid or gaseous.

:: Paper No: RH2EC-2021-10 ::

THE ECONOMICS AND THE ENVIRONMENTAL BENIGNITY OF DIFFEREN COLOURS OF HYDROGEN

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Due to the increasing emissions from the transport sector, as well as due to the rapidly increasing use of renewable energy sources in the electricity generation over the last years, interest in hydrogen is raising again. Hydrogen used in fuel cell vehicles can contribute to the decarbonization of the transport systems, Moreover, hydrogen used as a storage for renewable energy could contribute to the balance of the energy systems. However, most important is the environmental beingness of hydrogen, especially the over-all CO2 emissions. The major objective of this paper is to discuss economic and environmental performance of hydrogen and a major barrier for the faster deployment of hydrogen and fuel cell vehicles. To differ various ways of hydrogen production depending on the primary energy sources used, three colours have been introduced. With the increasing challenges to integrate variable renewables in power systems, hydrogen production by electrolysis, so called green hydrogen, is becoming more relevant. The major conclusion is that the full environmental benefits of hydrogen use in any sector are highly dependent on the hydrogen production methods and primary sources used. The policy framework should support the shift from the gray to green hydrogen.

:: Paper No: RH2EC-2021-11 ::

GREEN HYDROGEN PROJECT IN INA

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The EU Hydrogen Strategy recognizes hydrogen as a key factor in energy transition and decarbonization. Hydrogen is a versatile energy carrier that can contribute to strategic targets of zero-emission mobility, integration of renewables and the decarbonization of industry in EU. This paper describes development of the Hydrogen project lead by Development of INA, d. d. The Project shall provide economic analysis for the entire hydrogen supply chain from production, transport to the use of hydrogen. Most important part of the Hydrogen project is the detailedproject development of demonstration business case – Project Zagreb. The Project Zagreb includes the establishment of the entire hydrogen supply chain (production, transport, refueling stations) for 20 city buses. INA can supply conventional or grey hydrogen currently and with this project wants to introduce low carbon and green hydrogen in its portfolio. Focus of the project is ongreen H2 production using PEM technology and renewable electricity, filling infrastructure and refueling stations. But also, synergies with existing assets for hydrogen production will be evaluated. This project will have a positive impact on INA's decarbonization aims, its renewable energy portfolio and it will contribute to overall introduction of hydrogen in transport system of Croatia.

:: Paper No: RH2EC-2021-12 ::

ELECTROCHEMICAL HYDROGEN COMPRESSOR: REVIEW

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Given that hydrogen is recognized as a key energy vector in the ongoing energy transition to a carbonneutral society, multiple research is being conducted to increase the progress of hydrogen technology development. Even though hydrogen has higher specific energy from natural gas and gasoline, when compared per unit volume at room temperature and atmospheric pressure, its energy density is lower. This difference can be compensated with hydrogen compression that requires less energy. Theoretically, compression could be possible with a proton exchange membrane electrolyzer, in the process of hydrogen production itself, if not for the hydrogen permeation to the oxygen side forming a potentially explosive mixture. An electrochemical hydrogen compressor with an analogous working principle presents the most promising solution due to its noiseless and vibration-free operation, modularity, absence of moving part, and higher efficiency compared to conventional mechanical compressors. Hydrogen purification and its extraction from gaseous mixtures are additional benefits that give electrochemical compression further advantage. This paper discusses the working principle of electrochemical hydrogen compression technology and its design development. The focus is on research trends, recent advances, and transpired challenges. In addition, reviewed literature aspects not studied sufficiently are highlighted, and future research directions proposed.

:: Paper No: RH2EC-2021-13 ::

GCMC HYDROGEN STORAGE ON SCHWARZITES AND SLIT-SHAPED PORES AT ROOM TEMPERATURE

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The hydrogen car is an alternative to the fossil fuelbased vehicles. The main problem of its technology is the onboard storage, to achieve the goal of reaching the same autonomy range as the gasoline cars, about 600 km. In thiscontext, the physisorption of hydrogen on solid porous materials is a storage method. This research field is promising and very active. Nanoporous carbons are a large group of carbon-based solid porous materials, that are supposed to be a set of slit-shaped pores of different pore widths. Alternative structures to the slit-shaped model are the schwarzites. On another hand, schwarzites themselves could be hydrogen storage materials. In the present paper, we have carried out and analyzed Grand Canonical Monte Carlo-Metropolis (GCMC) simulations of the hydrogen storage capacities of different types of carbon schwarzites and slit-shaped pores at 298.15 K and in the pressure range of 0.1-25 MPa. The width of the slit-shaped pores varies between 6 and 15 Å. Lennard- Jones potentials have been used to simulate the interactions between carbon atoms and hydrogen molecules on schwarzites and between the hydrogen molecules on schwarzites and slit-shaped pores. The interaction between the carbon graphene layers of the slit-shaped pores and the hydrogen molecules have been simulated by means of the Steele graphene potential. The hydrogen storage capacities of the schwarzites and slit-shaped pores obtained in the simulations are compared and analyzed.

:: Paper No: RH2EC-2021-14 ::

TRADE-OFFS STUDY BETWEEN RISK AND BENEFIT IN SAFETY DEVICE OF HYDROGEN REFUELING STATIONS BY USING A DYNAMIC PHYSICAL MODEL

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Hydrogen refueling stations (HRSs) are becoming common as the commercial service energy infrastructure. With the increase in HRSs, it is clear that a high level of economy and safety is crucial. The need for HRSs grows with the popularity of fuel cell vehicles (FCVs), but there are several

associated hazards. Japanese safety regulations have identified excess flow valves (EFVs) as safety devices that can reduce the risk of fire, vapor cloud explosions, injury, and property damage. The easiest alternative is to use a simple orifice. Furthermore, using a simple orifice can cause significant pressure loss in the hydrogen flow, which would increase the FCV refueling time. For this reason, a study of the trade-offs is carried on a model-based performance evaluation and quantitative risk assessment of HRSs for a high level of safety and economical operation. Based on results of this study targeting a typical HRS, the orifice can replace conventional EFV as an alternative safety device that enables. There is not significant disadvantage for the orifice compared with the EFVs regarding to time required to complete refueling the FCV tank based on evaluation with simulation using a dynamic physical model for HRS. While, there is not a large difference in terms of risk between the baseline configuration with EFVs and the alternative configuration using an orifice regarding hydrogen leakage.

:: Paper No: RH2EC-2021-15 ::

QUANTITATIVE RISK ASSESSMENT OF HYDROGEN REFUELING STATIONS BY USING A DYNAMIC PHYSICAL MODEL

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Hydrogen refueling stations (HRSs) in urban areas such as Tokyo (Japan) are located in congested areas with tall buildings and high population density. However, relatively small installations such HRSs have not been considered as the object in the quantitative risk assessment (QRA). Therefore, it is essential to conduct a detailed QRA and reduce the uncertainties. This study focuses on multi-physics system-level modeling and simulation of a target system implemented using Modelica. It can provide the hydrogen leakage rate based on the dynamic behavior of some parameters. We developed an HRS process model that demonstrates the practical behavior of hydrogen release in an HRS and calculated the dynamic leakage rate and individual risks of jet fires or vapor cloud explosions. We compared the risk contours based on the traditional model and the ones based on the physical model with hydrogen dynamic behavior. The results showed that the risk analysis was refined owing to the change of the leak position and the change of the leakage rate over time. The result implies that it is possible to discuss whether the risks around the station boundary are acceptable by evaluating the risks near the station in detail.

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:: Paper No: RH2EC-2021-16 ::

BLENDING OF HYDROGEN INTO NATURAL GAS DISTRIBUTION NETWORK – A REVIEW

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As part of climate change involving the reduction of pollutant emissions, new technologies will play an important role to support decarbonization of the gas distribution system with the aim of achieving zero greenhouse gas emissions by 2050. Operators from the gas industry are considering different options for adapting higher concentrations of renewable gases in gas networks. One of the technologies is blending hydrogen into natural gas, provided that it can be technically and safely distributed to end customers. Technical advantages and disadvantages related to the gas distribution system, the impact of hydrogen on the safety and durability of the whole system, gas quality, management and use of the gas appliances, have emerged from numerous studies. This paper presents an overview of problems from recorded studies of increased hydrogen concentration in natural gas, its impact on final consumption, technical parameters and gas installations at consumers. These impacts affect the entire gas infrastructure, and before mixing an analysis in each individual part of the gas distribution system is required. The application of a mixture of hydrogen and natural gas is one of the possible ways in decarbonisation of industry, households, reducing air pollution. A gas network that will transport and distribute a mixture of hydrogen and natural gas is one of the part of the energy transition to a low-carbon future.

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