



BOOK OF PROCEEDINGS

INTERNATIONAL CONFERENCE SUSTAINABLE MOBILITY

5-6 MARCH

2026

The INTEC International Conference brings together academics, researchers, policymakers and industry experts to discuss innovative approaches and collaborative solutions for a sustainable future in engineering and mobility. The conference will be hosted by POLIS University in Tirana, Albania, and co-organized by partners from across the EU as part of the Erasmus+ CBHE Project 101081873-ERASMUS-EDU-2022-CBHE-STRAND-2.



INTEC International Engineering Competence Centres to push sustainable mobility development in Albania and Montenegro
Project Reference: 101081873-ERASMUS-EDU-2022-CBHE-STRAND-2

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Project Partners:



INTEC International Conference
February 2026
POLIS University, Tirana, Albania

INTEC>>>



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February 2026
POLIS University, Tirana, Albania

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COMPARISON OF LIFECYCLE EMISSIONS OF A SUV WITH FUEL CELL AND BATTERY ELECTRIC POWERTRAINS

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Bhavin KAPADIA

Frankfurt University of Applied Sciences, Germany
bhavin.kapadia@fra-uas.de

Alper SAYIN

Frankfurt University of Applied Sciences, Germany

Sandra EISENTRÄGER

Frankfurt University of Applied Sciences, Germany

Abstract

In the foreseeable future Battery-Electric-Vehicle (BEV) numbers are expected to grow in Germany. Presently every other newly registered vehicle is a Sport-Utility-Vehicle (SUV). Further every other newly registered SUV is a BEV. The sales of Fuel-Cell-Electric Vehicles (FCEV) remain low despite the presence of platforms from manufacturers such as Toyota, Hyundai and prospectively BMW. Although both BEVs and FCEVs have zero tailpipe CO₂-Emissions, the lifecycle emissions impact is dependent on many factors. This study compares the lifecycle emissions of both powertrains using a comparable vehicle platform. The study considers the impact of the energy mix on the lifecycle emissions. The Hyundai vehicles Kona (BEV) and Nexa (FCEV) are used as the basis for providing estimates as both vehicles are comparable in terms of net weight and power. A model for estimating the lifecycle emission using ISO1404/44 is created representing the vehicle manufacturing (Cradle-to-Gate Emissions), usage (Well-to-Wheel Emissions) and disposal (End-of-Life Emissions). It is assumed that the vehicle chassis for both powertrains are the same, in order to distinguish the impact of the powertrains. The ECOinvent database has been used in the Open-LCA software to model manufacturing and transport processes of various systems in the vehicles. Two scenarios for lifecycle emissions were considered for a vehicle use of 200,000 km at the end of life. Firstly, the current energy mix in Germany is considered, followed by a scenario where 100 % renewable energy is used. The Cradle-to-Gate Emissions per vehicle for BEV powertrains were 2000 kg CO₂ higher than for FCEV while using the current energy mix in Germany. A break even of the emissions was reached

around 78000 km and over the 200,000 km the BEV vehicle emitted almost 5000 kg CO₂ lower than the FCEV. However, when the manufacturing and usage considered 100 % renewable energy, the FCEV emissions were almost 2000 kg CO₂ lower than the BEV. The fuel cell vehicle when used with 100 % renewable hydrogen emits lower lifecycle CO₂-emissions compared to a similar BEV vehicle. If the challenges on hydrogen availability are met, the powertrain has the potential of being a more environment friendly solution in the future, with the added benefit of comparable refueling times to conventional fossil fueled vehicles.

Keywords: FCEV, BEV, lifecycle emissions, sustainable mobility

I. INTRODUCTION

Globally, the transport sector accounts for around 16 % of the greenhouse gas emissions, with road transport being a dominant contributor [1]. In the European Union alone, nearly 25 % of energy-related CO₂-emissions originate from transport activities. Under the Fit-for-55 Targets the transport sector is expected to reduce the total emissions by 2035 by 55 % relative to the 1990 levels and a further reduction is targeted till 2050 [2].

Battery Electric Vehicles (BEV) and Fuel Cell Electric Vehicles (FCEV) are both regarded as possible solutions to meet these targets. The same requiring the widespread use of renewable energies in the energy sector in order to truly reduce greenhouse gas emissions. Further, the sport utility vehicle (SUV) segment has seen the largest development in the last 5 years finding the most resonance among consumers [3]. Many manufacturers have adapted their product portfolios with full-electric powertrains to cater to this demand. On the other hand, FCEVs have not been able to make inroads yet into the market as many countries still do not have adequate hydrogen infrastructure to address customer concerns. Germany has currently around 70 hydrogen filling stations and for the next decade the development and commissioning of a hydrogen supply network has been approved by the German supply network agency [4]. The production and use of FCEV is therefore expected to gain a higher prevalence.

The “zero-emission” capability of both these vehicles is local, however a variety of factors such as raw material generation, production process, energy mix, usage and disposal impact the true greenhouse savings that can be achieved as the vehicle numbers increase. Various studies show that BEVs emit lesser CO₂-emissions over the complete lifecycle in comparison to FCEVs due to a higher Well-to-Wheel efficiency [5,6]. The higher renewable energy demand for FCEV causing higher emissions. Further estimates show that BEVs have 60% lower lifecycle emissions than vehicles with biofuels [7], and that FCEV with current hydrogen supply emit only 15 % lower emissions. Another study by the Wilhuhn [8] showed that hydrogen from natural gas used in FCEVs produces higher emissions than a BEV. Even with the use of renewable hydrogen, emissions are

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higher CO₂-emissions over the lifecycle. For the manufacture of BEV the highest emission contributors are the battery production processes, while, for FCEV it is the platinum catalyst and hydrogen tank production.

All the different studies are not comparable, as the assumptions, scopes and parameters used vary the estimated emissions. Also, the studies mainly focus on mid-sized vehicles. A study from Sternberg. et al [9] compared specifically the Hyundai Nexu FCEV with a hypothetical BEV-SUV for different battery sizes. The present study provides an additional basis for comparing the FCEV and BEV-SUVs with the use of representative data of a real vehicle with a common glider. Additionally, the impact of using different sources of hydrogen is also studied.

II. METHODOLOGY

1. Life Cycle Assessment

The study follows the standardized Life Cycle Assessment methodology defined in ISO 14040 and ISO 14044. The midpoint method as per ReCipe 2016 has been used to estimate the global warming potential (GWP) [10]. A cradle-to-grave system boundary is applied, covering raw material extraction, vehicle production, the use phase, and end-of-life disposal. The recycling of components has not been considered. The Open LCA software is used to build a model of the different stages, with the use of an ECOinvent databank to cover standard industry process in regard to extraction of raw materials. The assessment accounts for the different phases from raw material extraction to the disposal of the vehicles as shown in Fig. 1. The Cradle-to-Gate emissions accounts for the extraction, processing and transport of materials that are used to manufacture fuel cell and battery vehicles, considering most likely locations for obtaining raw materials. The functional unit to estimate the CO₂-emissions is defined as one vehicle kilometer driven over a total lifetime distance of 200,000 km.

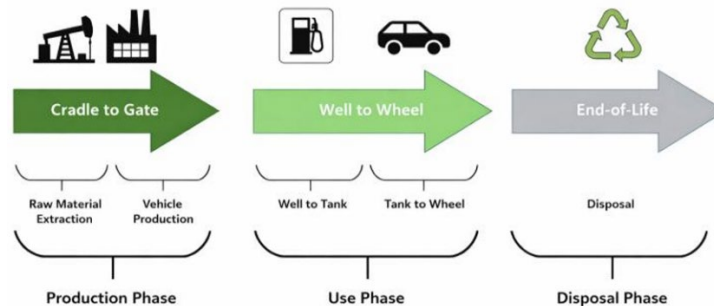


Figure 1. Life cycle estimate scope showing the phases being modeled. [11]

2. Vehicle selection and system boundaries

Two comparable mid-size sport utility vehicles were selected the Hyundai Kona Electric (BEV) and Hyundai Nexo (FCEV) were used for the lifecycle estimates. Both vehicles represent current market-ready technologies and offer similar vehicle size and performance characteristics. Manufacturer-specific data were supplemented with literature sources where necessary. The carriage (glider) was allotted the same mass for both vehicles so as to estimate the impact of the powertrain on the emissions over the lifecycle. The manufacturing of the vehicles was assumed to be in central Germany. In order to estimate the Tank-to-Wheel emissions during the use phase the Worldwide-Light-duty-Test-Procedure (WLTP-cycle) was used together with published data from the manufactures. The impact of using current energy mix in Germany was considered along-with a completely renewable energy mix.

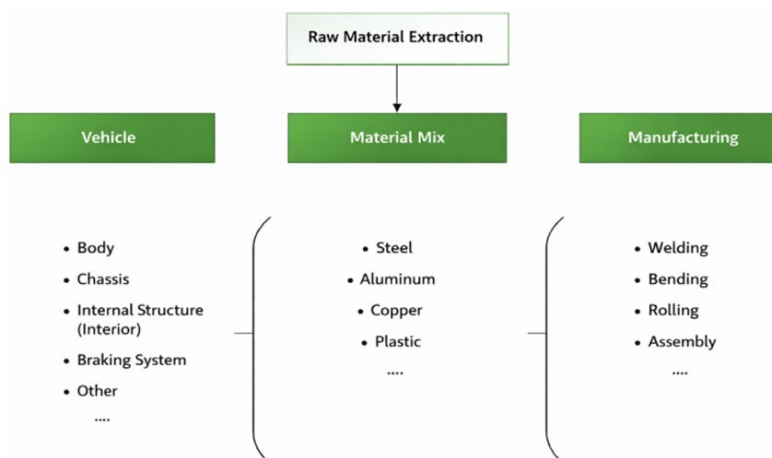


Figure 2. Glider model showing the raw materials and manufacturing processes. [11]

3. Inventory data and modeling

The life-cycle inventory was constructed using data from the Ecoinvent database and peer reviewed studies. The Fig 2. shows the Glider model used for the material extraction and manufacturing of different components belonging to it. The raw material extraction covered steel production out of Brazil, aluminum from Guinea, and copper from Chile. A 48-kWh nickel-manganese-cobalt NMC-lithium-ion battery production out of China was assumed. The cobalt and nickel extraction were modeled out of Congo and the Philippines respectively with the refinement being done in China.

The BEV-drivetrain was modeled using the raw material extraction and manufacturing of individual cells, the cooling system, packaging, the battery management system (BMS) and the build of the modules and packs. The additional components such as buffer battery, electric motor, power electronics and charger were also considered. For the FCEV the material extraction and manufacturing of fuel cell, the balance-of-plant (BOP) consisting of the air management, water management, fueling, and thermal management was considered. The hydrogen tank, control unit, battery, power electronics and electric motor were also modeled. As mentioned previously the use phase was modeled using the WLTP-cycle as per manufacturer data with assumed Level-2 charging efficiencies considering current German energy mix and 100 % renewable energy for the BEV. For the FCEV the origin of hydrogen was modeled using steam reforming of methane to represent the current availability and additionally 100 % green hydrogen from renewable sources was considered. The End-of-Life disposal was represented with a cut-off approach, thereby, not representing the recycling in order to complete the LCA. The pyrometallurgical and hydrometallurgical processing of the batteries was represented with a 50/50 mix. The glider, the electrical powertrain and buffer battery disposal were modeled using the representative Ecoinvent database process. For the FCEV the thermal treatment of the stack and tank was modeled. The BOP components are treated as 60% electronic and 40% plastic with the relevant disposal methods. The FCEV glider disposal is the same as that of the BEV. The End-of-life was assumed to be at 200,000 km of vehicle use.

III. RESULTS

The following section presents the results of the LCA for the two vehicle types considering the current energy mix in Germany and supply of hydrogen, as well as the estimates from a 100 % renewable energy mix. The Fig. 2 shows the results from the analysis. For the case with the current energy mix, the CO₂ -Emissions from the BEV are 18% lower than that of the FCEV. For the BEV, battery production represents the largest single source of emissions during the production phase. The CO₂ emissions are almost 50% higher for the manufacturing of the battery powertrain compared to the FCEV-powertrain. For the FCEV, emissions are dominated by the fuel cell system and high-pressure hydrogen tanks. During the use phase a break-even of both vehicle emission is reached at 78000 km. Thereafter the FCEV emissions are 60% higher in comparison to the BEV till 20000 km. The fossil-based source of the hydrogen from the natural gas reforming processes causing the higher well-to-wheel-emissions. The End-of Life phase emissions are similar for both powertrains. As the same glider has been used, the corresponding manufacturing emissions are also the same.

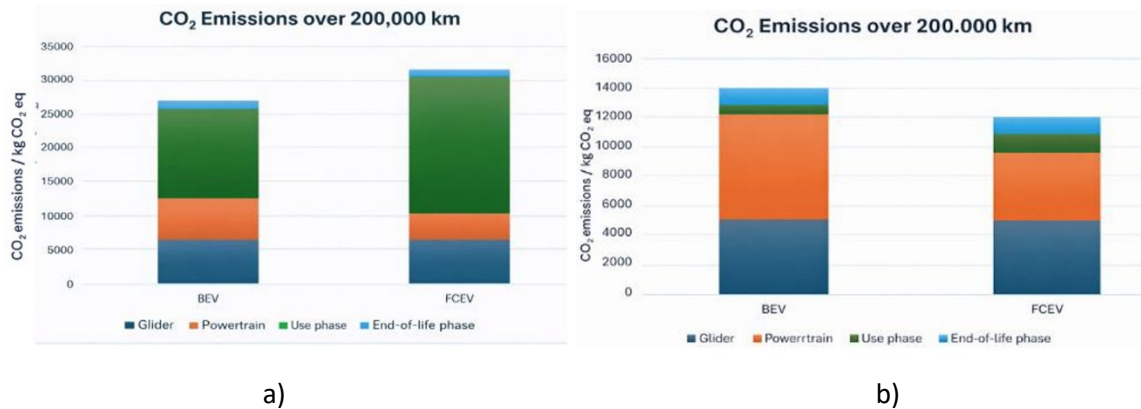


Figure 3. Comparison of CO₂-Emissions for the powertrains using (a) current German energy mix and (b) 100 % renewable energy.

With the pure renewable energy scenario (Fig 2. (b)), lifecycle emissions for the BEV reduced by almost 50% whereas for the FCEV the reduction is almost 63 %. The fossil energy dependant reforming process for the hydrogen production no longer contributes to the use phase emissions and thereby showing that the FCEV powertrain emits almost 2000 kg lesser CO₂ in comparison to the BEV.

The results of the study were compared to another similar publication [9]. The values of the powertrain emissions are 10-20% lower than those from the study. The differences are attributed to variations in the production phase estimates. The electrical powertrain efficiency variations can also cause differences in the total lifecycle emission calculations.

IV. DISCUSSIONS AND CONCLUSION

This paper presents a lifecycle emission comparison of BEV and FCEV technologies for a SUV. A model representing the manufacturing, use and end-of-life phases for both types of vehicles was created. For the current energy mix in Germany and source of hydrogen the BEV emissions were found to be significantly lower than those of a FCEV. However, with a totally renewable source of electricity the FCEV emissions are lower than the BEV. The findings highlight the importance of the energy system on total emission savings for different technologies.

BEVs currently benefit from higher overall energy efficiency and a more mature electricity infrastructure. FCEVs show potential advantages in terms of refueling time and driving range, particularly for heavy-duty or long-distance applications. However, their climate performance is highly dependent on the large-scale availability of green hydrogen. The study also highlights some of the uncertainties in such estimates. The data availability, assumptions regarding vehicle lifetime, processes and exclusion of recycling credits impact the final results. Nevertheless, the relative

comparison between BEV and FCEV remains robust across scenarios. The study underscores the importance of coupling vehicle electrification strategies with the decarbonization of the energy sector. Future work plans to extend the analysis to additional environmental impact categories and including recycling scenarios.

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International conference on sustainable mobility

Agenda

Project title: International Engineering Competence Centres to push Sustainable
 Mobility Development in Albania and Montenegro
Acronym: INTEC

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| Work package | |
| WP11 | International conference |
| TASK | |
| 11.4 | Community Building Events |

| | |
|----------------------|---|
| Dates | 05.03.-06.03.2026 |
| City | Tirana |
| Meeting venue | POLIS University Entrance Hall |
| Address | Rr. Bylis 12, Kodi Postar 1051, Kutia Postare 2995, Tirana, Albania |

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| 05.03.2026 | |
| Entrance Hall, POLIS University | |
| 8:30 - 9:00 | Registration |
| 9:00 - 9:30 | Opening Performance |
| Welcome session - Auditorium A5 (Ground floor) | |
| 9:30 - 10:00 | Opening Remarks Dr. Elona Karafili (Vice Rector, POLIS University) Dr. Flora Krasniqi (Head of Office of Projects and Internationalization, POLIS University) DI Daniela Wenzl (INTEC Project Coordinator) |
| Auditorium A5 (Ground floor) | |
| 10:00 - 11:00 | Keynote speakers DI Horst Pflügl AVL Collaborative Research for sustainable Mobility DPSHTRR Representative - (General Directorate of Road Transport Services in Albania) |
| 11:15 - 11:30 | Coffee break (Moving into parallel sessions) |

| 11:30 | SESSION 1: POLITICAL AND REGULATORY FRAMEWORK AULA B1 | SESSION 2: TECHNOLOGICAL INNOVATION AULA B4 |
|---------------|--|--|
| 11:30 - 11:45 | Opening Session: Prof. Emeritus dr Nataša Gospić (FSKL) | Opening Session: Associate Prof. Ivan Tolj (US) |
| 11:45 - 12:00 | Integrating Event Data Recorder (EDR) Technology into Sustainable Road Safety Frameworks within the European Green Deal Eriselda Alimeti, Parid Milo, Mentor Çejku, Anis Sulejmani, Odhisea Koça | Empirical Comparative Study of Structural CFRP Sandwich Structure Inserts for Out-of-Plane loads Imre Kovács |
| 12:00 - 12:15 | Infrastructure Readiness for Sustainable Mobility: EU Frameworks and the Case of Albania Ervin Kalemaj, Parid Milo, Mentor Çejku, Anis Sulejmani, Odhisea Koça | The Role of Intermodal Transportation for the Sustainable Mobility Márton Kovács |
| 12:15 - 12:30 | Review of the Evolution of International Ship Energy Efficiency Regulations and the Albanian context Dr. Blenard Xhaferaj, Doklejda Hodaj | Impact of Heat Pump Systems on Winter Energy Use and Driving Range in Battery Electric Vehicles Luis Henrique Pereira Martins |
| 12:30 - 12:45 | Renewable Energy Procurement (CPPA) and Transport Electrification: European Perspectives and Albanian Challenge Antonio Ndoci, Anis Sulejmani, Odhisea Koça, Mentor Çejku, Parid Milo | Liquid Cooling Systems for Electric Vehicle Batteries: Improving Safety, Performance and Sustainability João Miguel de Almeida Ribeiro Silva |
| 12:45 - 13:00 | The Current Status of Autonomous Vehicle | Analysis of Battery Charging and Discharging Behavior for Electric Vehicle Applications Leona Markic, Luka Filipović |

| | | |
|----------------------|---|--|
| | Technology Adoption in the Balkan Region Darjana Lopičić, Oliver Popović, Miloš Ilić, Bojan Kocić | |
| 13:00 - 14:00 | Lunch | |
| 14:00 - 14:15 | Reviewing the European Green Deal in Energy, Mobility and Industry Veselinka Calasan, Ivana Ognjanović | Automotive Cooling Systems Sustainability: A Focus on the Expansion Tank Ana Inês Barbeiro Casimiro |
| 14:15 - 14:30 | The European Green Deal and its National Implementation: From Strategy to Practice Blerina Bektashi, Andi Bektashi | Design and Development of a Constant-Volume Combustion Chamber for Optical Investigation of Hydrogen and Water Injection Under Engine-like Conditions Julius Hollerith, Prof. Dr. Bhavin Kapadia |
| 14:30 - 14:45 | From Prediction to Regulation: Evidence Production Approaches in Autonomous Mobility Research and Their Policy Implications Sadmira Malaj | Emission Reduction of Marine Propulsion Systems in SECA Zones Through the Integration of Hydrogen Technologies Motaleb Miri, Ivan Radaš, Marija Mandić, Ivan Tolj |
| 14:45 - 15:00 | Questions and Discussion | A Comprehensive Analysis of Ventilation System for Enhanced Energy Efficiency in Marine Propulsion Applications Sara Blašković, Gojmir Radica, Jakov Šimunović |

| | | |
|---------------|--|--|
| 15:00 - 15:15 | | <p>Design and Topology Optimization of a Lightweight Chain Sprocket for Electric Motorcycle Applications</p> <p>Teo Čolović, Ivo Marinić-Kragić</p> |
| 15:15 - 15:30 | <p>SESSION 3: ECONOMIC AND BUSINESS PRESPECTIVES + CASE STUDIES AND GOOD PRACTICES</p> <p>Aula B1</p> <p>Opening Session: Dr. Anis Sulejmani (PUT)</p> | <p>Questions and Discussion</p> |
| 15:30 - 15:45 | <p>Managing Renewable Energy Resources as a Foundation for Sustainable Mobility Transitions</p> <p>Deivi Sinanaliaj, Martin Bektashi</p> | |
| 15:45 - 16:00 | <p>Feasibility of Electric Bus deployment in Montenegro: A Case Study of Budva (Erasmus+ INTEC / IECC Context)</p> <p>Anastasija Mrkajic, Vinko Nikic.</p> | |
| 16:00 -16:15 | <p>Children Paths as an Urban Regeneration Strategy: Naim Frasheri Study Case</p> <p>Dejvi Dauti</p> | |
| 16:15 - 16:45 | <p>Questions and Discussion</p> | |
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International conference on sustainable mobility

Agenda

Project title: International Engineering Competence Centres to push Sustainable Mobility Development in Albania and Montenegro
Acronym: INTEC

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| Work package | |
| WP11 | International conference |
| TASK | |
| 11.4 | Community Building Events |

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| Dates | 05.03.-06.03.2026 |
| City | Tirana |
| Meeting venue | POLIS University Entrance Hall |
| Address | Rr. Bylis 12, Kodi Postar 1051, Kutia Postare 2995, Tirana, Albania |

| 06.03.2026 | | |
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| First Floor Hall, POLIS University | | |
| 8:30 – 9:00 | Registration | |
| 9:00– 9:15 | SESSION 4: SOCIAL AND ENVIRONMENTAL IMPACT AULA B1 | SESSION 5: FUTURE SCENARIOS AULA B4 |
| 9:00 – 9:15 | Opening Session: Prof. Dr. Bhavin Kapadia (FHF) | Opening Session: MA Adrian Millward-Sadler (FHJ) |
| 9:15 – 9:30 | Comparison of Lifecycle Emissions of a SUV with Fuel Cell and Battery Electric Powertrains - Bhavin Kapadia, Alper Sayin, Sandra Eisenträger | GENAI Literacy as a Transversal Skill for Emerging Professionals: Implications for Sustainability- Critical Knowledge Work - Adrian Millward-Sadler |
| 9:30 – 9:45 | Smart Mobility Technologies and their Impact on Urban Sustainability: Insights from | Effects of Technical Traffic Calming Measures – Filip Perović |

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| | European and Western Balkan Cities – Alma Gjonaj, Vjola Ziu | |
| 9:45 – 10:00 | The Disappearing Squares: Social and Environmental Impacts of Urban Mobility Planning in Durres – Arjola Sava | Cybersecurity Vulnerabilities in Electric Vehicle Operating Systems: A Global Awareness Analysis – Aleksa Radević |
| 10:00 – 10:15 | The City that Demands Continuous Movement: The Disappearance of the Right not to Move within the Framework of Sustainable Mobility – Avrili Meshi | Development of a risk assessment model for the transport of hazardous materials using ALOHA and GIS software tools – Marko Radetić |
| 10:15 – 10:30 | Between Rhetoric and Reality: Discursive Framings, Greenwashing and Outcomes in Sustainable Mobility – Kejsi Veselagu | Mapping Distance and Time Leveraging Isochrone Intelligence in Emerging Cities – Andia Vllamasi, Erjon Cobani |
| 10:30 – 10:45 | Reimagining the City Through Green Mobility Strategies: The Case of Tirana – Vjola Ziu, Alma Gjonaj | Can AI develop its Own “Taste” Automotive Design? – Gregor Andoni, Kristjana Meço |
| Coffee Break | | |
| 11:00 – 11:15 | Linking Morphology, Perceived Safety, and Sustainable Mobility in Post-Socialist Urban Contexts– Sindi Doce | Optimizing Public Transport Corridors Using AI-Based Scenario Modelling: A case Study on Tirana’s Ring Road – Erjon Çobani, Julian Beqiri, Merita Guri |
| 11:15 – 11:30 | Towards Sustainable Transport: A Comparative Analysis of Electric Vehicle Adoption in Montenegro and Albania – Radmila Milić | Threat Landscape and Multi-Layered Protection Mechanisms for Autonomous and Electric Vehicle Systems – Marko Asanovic, Oliver Popović, Zoran Avramović, Nataša Gospić |

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| 11:30 - 11:45 | Questions and Discussion | Cybersecurity Challenges in Modern Vehicular Communication Networks - Aleksandar Grgurević, Nataša Gospić, Oliver Popović |
| 11:45 - 12:00 | | Green Transition in Albania: Challenges and Future Actions - Erik Kushta, Andi Hyka, Enea Nasto |
| 12:00 - 12:15 | SESSION 6: CONTROVERSIES AND CHALLENGES Aula B1 | Use of AI in the Process of Green Transformation and Impact on Public Health - Esmeralda Hamiti, Federika Alliaj, Kristi Metushi |
| | Opening Session: Prof. Kristofor Lapa (UV) | |
| 12:15-12:30 | The Adoption of Electric Vehicles in Albania: A Comparative Study with Other Western Balkan Countries - Doklejšda Hodaj, Andrea Lapa | Development of an Automatic Traffic Sign Detection System Using YOLOv8 - Valentina Vojinović, Luka Filipović |
| 12:30-12:45 | Application of Quality Tools in the Analysis of Factors Influencing the Development of Electromobility in Montenegro - Jelena Šaković Jovanović, Draško Jovanović, Mirjana Grdinić Rakonjac, Marko Lučić, Miloš Perović, Aleksandar Vujović, Gordana Radulović | The Historical Development of Artificial Intelligence and Its Influence on the job market in Automotive Engineering - David Josef Pilgram |
| 12:45 - 13:45 | Questions and Discussion | Questions and Discussion |
| 13:45 | Lunch | |