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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:
FH JOANNEUM University of Applied Sciences · Frankfurt University of Applied Sciences · UPT · UCG · UDG · AVL · GAMA-AUTO · ALFA Centar

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Partner Universities

Project Coordinator: FH JOANNEUM Gesellschaft mbH (FHJ), Austria
Frankfurt University of Applied Sciences (FRA-UAS), Germany
University of Split (US), Croatia
POLIS University (POLIS), Albania
Polytechnic University of Tirana (PUT), Albania
University of Vlore "Ismail Qemali" (UV), Albania
University of Montenegro (UOM), Montenegro
Adriatic University Bar (FSKL), Montenegro
University of Donja Gorica (UDG), Montenegro
AVL List GmbH (AVL), Austria
Gama Auto d.o.o. (GA), Montenegro
NVO Alfa Centar (AC), Montenegro

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Dr. Elona Karafili
Dr. Flora Krasniqi

Conference Keynote Speaker

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MSc. Mine Bushi, General Directorate of Road Transport Services in Albania

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11

LIQUID COOLING SYSTEMS FOR ELECTRIC VEHICLE BATTERIES: IMPROVING SAFETY, PERFORMANCE AND SUSTAINABILITY

DOI: 10.37199/c41001011

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Abstract

As electric vehicles become more common, one thing that keeps showing up as a real challenge is how to keep their batteries at the right temperature. It's something most people never think about when they get into an electric vehicle, but the truth is that temperature is a really important factor in battery functioning. They work best in a narrow temperature band, and when they drift too far from it, either too hot or too cold, their behaviour changes quite a lot. High temperatures speed up wear and can lead to safety problems, while cold conditions make the car less responsive and slow down charging significantly. Because of this, manufacturers have turned to liquid cooling systems. The basic idea isn't anything new or mysterious: a coolant flows through small tubes or plates near the battery cells and carries heat away. But in the context of electric vehicles, this relatively simple concept makes a massive difference. Liquids just move heat much better than air, so the system manages to keep the whole battery pack more balanced and prevents degradation. The impact of this temperature control is more noticeable than drivers might expect. When the battery is kept stable, the car performs more consistently, even during fast charging or long trips. It also tends to last longer, meaning fewer battery replacements and less environmental waste. For something that the driver never sees, liquid cooling quietly improves safety, performance, and sustainability at the same time. In the last few years, the field has evolved quickly. Some companies are experimenting with immersive cooling using special non-conductive liquids, while others focus on tiny micro-channels that extract heat more efficiently without making the pack heavier. This paper looks at how these liquid cooling systems work, why they matter so much for modern electric vehicles, and how they are helping shape a more reliable and sustainable future for electric mobility. It's a technology that works in the background, but without it, electric vehicles simply wouldn't perform the way we expect them to.

Keywords*:* electric vehicles; battery thermal management; liquid cooling systems; batteries; energy efficiency

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I. INTRODUCTION

The automotive industry is looking at a significant transformation. To reduce carbon emissions and fight climate change issues, many countries are pushing for the adoption of Electric Vehicles (EVs). However, for EVs to replace traditional cars completely, they must overcome barriers such as limited ranges and long charging times. To address this, manufacturers are pushing for Extreme Fast Charging (XFC) capabilities, aiming for power levels reaching 350 kW (Tu et al., 2019). This rapid energy transfer generates excessive heat within the battery pack, the vehicle's most critical component. Therefore, advanced thermal management is essential not only to ensure safety but to guarantee the viability of the next generation of EV's (Ma et al., 2018).

For these batteries to be safe they need to be in a specific temperature range. According to recent studies, lithium-ion batteries work best in a range between 15°C and 35°C (Ma et al., 2018). If the temperature gets too high, the battery degrades faster, and in extreme cases, it can lead to thermal runaway and fire. On the other hand, if it is too cold, the battery loses capacity and charging becomes very slow. Therefore, keeping the battery at the right temperature is not just about performance, it is a safety requirement.

This paper focuses on Liquid Cooling Systems, which are currently the most effective solution for this problem. Compared to air cooling, liquid systems are more complex but offer much better heat transfer capabilities.

II. METHODS

This study is based on a review of recent scientific literature regarding Battery Thermal Management Systems for electric vehicles. The main objective was to analyse and compare the performance of different liquid cooling technologies currently available or in development.

The research was conducted using academic databases such as Google Scholar and ScienceDirect. The search focused on the keywords, "liquid cooling systems", "battery thermal management", "EV safety" and “fast charging”.

This paper synthesizes findings from recent literature to provide a comparative review of cold plate and immersion cooling systems. Rather than presenting new experimental data, the analysis evaluates established performance metrics, alongside considerations of system complexity. The primary objective is to determine which technology offers the most effective solution for maintaining the battery within the optimal range of 15°C to 35°C.

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III. RESULTS

This section presents the findings of the literature review regarding the current state of liquid cooling technologies for electric vehicle batteries. The analysis focuses on the two main categories of liquid thermal management: indirect cooling (cold plates) and direct cooling (immersion). In the end, the air-cooling method is also compared

1. Indirect liquid cooling (cold plates)

The most widely used thermal management strategy in the current electric vehicle market is indirect liquid cooling. In this method, the cooling fluid does not come into direct contact with the battery cells. Instead, the liquid flows through metal channels or plates, commonly known as "cold plates," which are placed between the battery modules or at the bottom of the pack.

The working principle relies on thermal conduction. The heat generated by the lithium-ion cells is transferred to the metal plate (usually aluminium due to its high thermal conductivity) and then to the coolant flowing inside the channels. The coolant is typically a mixture of water and ethylene glycol, which is pumped through the system to a radiator where the heat is released into the environment.

Figure 1 illustrates a typical experimental setup of an indirect liquid cooling system. The configuration consists of an aluminium cold plate with copper tubes, which serve as the channels for the coolant circulation. A thermal interface material is usually applied between the battery cell and the plate to minimize air gaps and improve heat conduction.

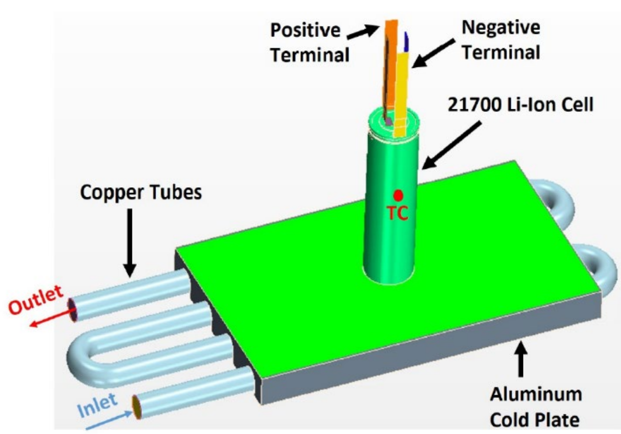

Figure 1. Schematic of indirect liquid cooling setup. Adapted from Dubey et al. (2021).

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Major manufacturers prefer this system because it offers a good balance between cooling performance and safety. Since the liquid is physically separated from the electrical components, the risk of short circuits is minimized.

However, indirect cooling has limitations, particularly regarding the interface between the cells and the cooling plate. Since the metal cannot perfectly conform to the battery surface, a Thermal Interface Material (TIM) is required to fill air gaps. While essential, this TIM layer adds thermal resistance to the system, limiting the heat transfer rate (Dubey et al., 2021). Over time these materials can degrade, potentially leading to increased cell temperatures and reduced cooling effectiveness as the vehicle ages.

2. Direct liquid cooling (immersion)

An emerging alternative to cold plates is direct liquid cooling, often referred to as immersion cooling. In this innovative approach, the entire battery module or the individual cells are submerged directly into a dielectric fluid, as shown in Figure 2. Unlike water-glycol mixtures used in cold plates, this fluid must be electrically non-conductive to prevent short circuits between the battery tabs. Engineered fluids are typically used, possessing high breakdown voltages and low viscosity (Dubey et al., 2021). These properties allow the fluid to flow freely between individual cells, ensuring that heat is removed equally from the entire surface area of the cylindrical cell, rather than just from the cooling tab or sidewall.

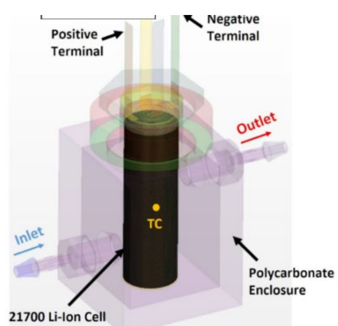

Figure 2. Schematic representation of the experimental immersion cooling. Adapted from Dubey et al. (2021).

This method solves the main limitation of indirect cooling: thermal resistance. Because the liquid surrounds the entire surface of the cell, heat extraction is significantly faster and more uniform. According to comparative studies, direct immersion cooling shows better thermal performance than cold-plate cooling, reducing the maximum temperature of the cells more effectively during fast charging cycles (Dubey et al., 2021).

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Besides performance, immersion cooling offers safety benefits. The large volume of fluid acts as a thermal buffer, which is highly effective in suppressing thermal runaway propagation in case of a single cell failure. However, this technology faces challenges regarding weight and cost. The dielectric fluids are expensive and heavier than the water-glycol mixtures used in cold plates, and the battery casing must be perfectly sealed to prevent leaks, which increases the manufacturing complexity.

3. Comparison of cooling methods

To evaluate the usage of these technologies for future electric vehicles, it is essential to compare their key characteristics. While indirect liquid cooling is currently the industry standard due to its maturity and lower cost, direct immersion cooling offers superior thermal management capabilities that may be required for even faster charging applications.

Table 1 summarizes the comparison between the two liquid cooling methods and the traditional air-cooling system. The data highlights efficiency, system complexity, costs and safety.

Table 1. Comparison of battery thermal management systems.

	Air cooling	***Indirect liquid cooling (Cold plates)***	***Direct Liquid Cooling (Immersion)***
Cooling fluid	Air	Water-Glycol	Dielectric fluid
Heat transfer	Low	High	Very high
System complexity	Low	High (Pumps, radiators)	High (Sealing, heavy fluids)
Cost	Low	Medium	High
Safety	Low (Propagation risk)	Medium	High (Supresses fire)

IV. CONCLUSION

The analysis of the current literature clearly indicates that liquid cooling is the superior technology for modern electric vehicles. While air cooling was sufficient for early EV models with smaller batteries and lower charging speeds, it is no longer viable for the high-performance vehicles of today.

While immersion cooling demonstrates superior thermal performance, it introduces significant challenges regarding weight and volume. Filling a battery pack with dielectric fluid adds substantial

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mass to the vehicle, which can negatively impact the overall energy density and driving range (Dubey et al., 2021). In contrast, indirect cooling systems are generally lighter and more compact, which explains their current dominance in the mass market despite their lower peak cooling capacity.

Beyond performance, thermal management plays a critical role in sustainability. By keeping the battery within the optimal temperature range (15°C–35°C), liquid cooling systems extend the lifespan of the battery pack. This has a direct environmental impact: batteries that last longer delay the need for replacement and recycling. Studies indicate that optimized cooling strategies can reduce the battery life cycle carbon footprint by up to 25% (Lander et al., 2021).

In conclusion, liquid cooling systems are not just a technical necessity but a key enabler for the widespread adoption of electric mobility. Future work should focus on the development of lighter dielectric fluids and the optimization of flow channel geometries to minimize the weight penalty of immersion systems. Additionally, life-cycle assessments analysing the recyclability of these specialized fluids will be essential to fully validate the sustainability credentials of direct liquid cooling (Lander et al., 2021).

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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

Work package	
WP11	**International conference**
TASK	
11.4	Coummunity 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

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)**

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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

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	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 Ognjanovic	**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** Motalleb 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

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

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WP11	International conference
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11.4	Coummunity 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

06.03.2026		
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 Opening Session: Prof. Kristofor Lapa (UV)	**Use of AI in the Process of Green Transformation and Impact on Public Health** - Esmeralda Hamiti, Federika Alliaj, Kristi Metushi
12:15-12:30	**The Adoption of Electric Vehicles in Albania: A Comparative Study with Other Western Balkan Countries** - Doklejda 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	

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