University of Southampton

Proceedings of the 1st International Workshop on Energy Transition to Net Zero Energy Reliability, Risk, and Resilience (ETZE R3)

PREFACE

The International Workshop on Energy Transition to Zero Carbon: Reliability, Risk, and Resilience is a joint effort by the B. John Garrick Institute for the Risk Sciences at the University of California Los Angeles (UCLA-GIRS) and the European Safety and Reliability (ESREL) Conference.

ETZE R3 is a ESREL workshop consist of multiple sessions designed to be a platform for cross-industrial and interdisciplinary effort and knowledge exchange on risk and resilience of energy transition technologies to net zero.

The workshop gathers experts from academia, industry, and regulatory agencies to discuss challenges and potential solutions for energy transition technologies to net zero from different perspectives.

This workshop complements existing sessions and workshops organized around specific types of net zero energy risk and resilience assessment.

ETZE R3 distinguishes itself from these events by addressing the energy transition issues and risk and resilience topics together and proposing possible solutions for safe and reliable transition to net zero energies.

ETZE R3-2023 was held at the University of Southampton, United Kingdom, on 3rd-7th September 2023, and gathered **77** participants from **34** organizations from around the globe.

This report summarizes ETZE R3-2023 workshop. It provides an overview of the main points raised by a community of experts on the current status of risk issues of energy transition to net zero methods. It also outlines research directions for safer, more reliable and resilient net zero technologies.

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1 INTRODUCTION

We must not let the risks of energy transition to zero-carbon turn into an excuse to slow down the journey to clean energy. There is an urgent need to understand the risk of an energy system that is transitioning to zero-carbon. The current fossil fuel-based infrastructures are not ready for the new energy carriers such as hydrogen, and infrastructure risks should be studied from different perspectives. Introducing new energy technologies to the current energy infrastructure can increase the system vulnerability and will result in new potential risks to the system.

The risk of climate change on energy systems under transition is also an important aspect that is often neglected. Prior research on long-term energy scenarios generally has considered the effects of average climate changes on energy demand and generation. But heat waves, heavy storms, wildfires, and other climate-related extremes can substantially affect electricity/gas supply and demand, disrupt operations, and damage infrastructure. Long-term energy system planning and modeling needs to further incorporate the risk of climate variability on energy systems.

This series of annual workshop provide a platform for risk, reliability, safety researchers and industry professionals to present and discuss the latest developments in modelling and analysis of energy transition risks. The focus is on how these models and analysis can be used to inform decision making to manage the risk of failure of new energy solutions meeting the energy demand and thus comprising the energy transition to zero-carbon.

ETZE R3-2023 is the first edition of the workshop series on Energy Transition to Zero Carbon: Reliability, Risk, and Resilience, held at the University of Southampton, United Kingdom, on 3rd-7th September 2023.

The workshop program was distributed over three days/six sessions, counted nearly **77** participants from different backgrounds, representing a diversity of industries, and from **34** different institutions.

This proceeding summarizes the discussions held at the workshop and provides insights on the roadmap of the workshop for the following years.

2 ESREL2023 WORKSHOP FINDINGS

In ESREL 2023, 27 papers were submitted and here is the number of papers based on the title classification.

Hydrogen Safety
8 papers

Wind Turbine/Farm Analysis
8 papers

System Level Technology Assessment
4 papers

Cybersecurity and Software Development
4 papers

Regulatory
1 paper

Modeling and Simulation/ Methodology
2 papers

The papers per classification are presented in attachment A.

2.1 Hydrogen Safety

The exploration of hydrogen-related safety across the referenced papers reveals a multifaceted approach to managing potential risks associated with hydrogen technologies. Authors across these studies address diverse aspects, including the systematic analysis of undesired events, such as leaks or failures, to establish a comprehensive safety assessment framework. Furthermore, the incorporation of artificial intelligence techniques for understanding and mitigating hydrogen embrittlement in pipeline steels showcases a commitment to cutting-edge technologies for safety enhancement. Evaluations of risks associated with hydrogen transport scenarios in oceanic environments contribute to maritime safety considerations, while the review of safety standards and guidelines for green hydrogen production emphasizes the importance of integrating safety measures into sustainable practices. Additionally, the papers collectively stress the need for quantitative risk assessment and strategic risk management throughout the lifecycle of hydrogen facilities and projects. The numerical modeling of liquid hydrogen tanks during fire events provides critical insights into emergency scenarios, contributing to the development of robust safety measures. Altogether, these papers underscore the significance of a holistic and technologically advanced approach to ensuring the safety of hydrogen-related processes and facilities.

2.2 Wind Turbine/Farm Analysis

The diverse array of papers collectively contributes to a comprehensive analysis of wind turbines and wind farms, addressing various facets crucial for their reliability, safety, and efficiency. Studies such as “Bearing Health and Safety Analysis to improve the reliability and efficiency of Horizontal Axis Wind Turbine (HAWT)” focus on specific components, like bearings, to enhance the overall performance of Horizontal Axis Wind Turbines (HAWTs). Meanwhile, “Comparative Risk Assessment of Wind Turbine Accidents from a Societal Perspective” offers a holistic viewpoint on the societal risks associated with wind turbine accidents. The integration of deep learning approaches in “Wind turbine bearing prognostics” highlights technological advancements in predicting and preventing potential failures. Models like the MBSA model for offshore wind farms aim to evaluate and enhance the production availability, contributing to efficient operational strategies. The examination of threat perception and countermeasures in “Perception of threats in Offshore Windfarms” emphasizes the importance of security in offshore wind energy installations. Other papers delve into the impact of environmental conditions on power converter reliability, fusion-driven fault diagnosis, and even extend ecological resilience concepts to model critical infrastructure in offshore wind farms. This collective body of research not only advances our understanding of the intricate dynamics within wind turbines and farms but also informs strategies for improving their resilience, safety, and overall performance.

2.3 System Level Technology Assessment

The papers collectively contribute to the field of system-level technology assessment, offering insights into the risks, capabilities, and implementation challenges of diverse energy technologies. “Comparative Accident Risk Assessment of Energy System Technologies for the Energy Transition in OECD Countries” provides a comprehensive overview of the accident risks associated with various energy system technologies, contributing to informed decision-making during the energy transition. The paper on the “Connection capability of distributed generation units in a power system under Active Network Management” explores the integration challenges of distributed generation units, highlighting the importance of effective network management for accommodating decentralized energy sources. “Meeting new electrification needs” delves into how a Norwegian grid operator is enhancing coordination by developing a public capacity simulation service, emphasizing the role of technology in addressing evolving electrification demands. Lastly, “Risk Assessment and Reliability in the implementation of Urban Electric Mobility Projects” sheds light on the challenges and reliability considerations in implementing urban electric mobility projects, providing valuable insights for the sustainable integration of electric vehicles into urban environments. Together, these papers contribute to a holistic understanding of system-level technology assessment, encompassing safety, reliability, and adaptability in the context of evolving energy systems and urban mobility projects.

2.4 Cybersecurity and Software Development

The papers collectively delve into the intersection of cybersecurity and software development, addressing key challenges and proposing strategies for improvement in different domains. “Cybersecurity in railway” explores the role of independent assessors in ensuring cybersecurity in railway systems, emphasizing the need for alternative approaches for effective cybersecurity assurance. In “Increasing effectiveness of development and operation of software for cyber-physical systems,” the focus is on enhancing the efficiency of software development and operation for cyber-physical systems, recognizing the importance of robust software in securing interconnected physical and digital elements. “Practical Barriers in Implementing Intrusion Detection Systems in Control Systems in Electric Utilities” sheds light on the practical challenges associated with implementing intrusion detection systems in control systems within electric utilities, highlighting the complexities involved in safeguarding critical infrastructure. “Methodological insights for the prevention of cyber-attacks risks in the energy sector” provides empirical insights into the prevention of cyber-attacks in the energy sector, contributing methodological perspectives for risk mitigation. These papers collectively contribute to advancing the understanding of the complex dynamics between cybersecurity and software development, offering insights and practical considerations to fortify systems against cyber threats across diverse industries.

2.5 Regulatory

The paper on “Korea SDP Regulatory Process based on Regulatory PSA Model” by Dongwon Lee and Yongjin Kim explores the regulatory process within the context of Software Defined Perimeter (SDP) in Korea. The regulatory PSA (Preliminary Systematic Analysis) model serves as the foundation for understanding and analyzing the regulatory landscape for SDP implementation. By examining the regulatory process, the paper contributes valuable insights into the strategic considerations and systematic approaches involved in establishing regulatory frameworks for SDP technologies in Korea. This research is pivotal in shedding light on the regulatory dynamics, providing a basis for informed decision-making and policy development to ensure the secure and efficient deployment of SDP in the region.

2.6 Modeling and Simulation/ Methodology

The papers on modeling and simulation/methodology provide significant contributions to understanding and enhancing the resilience of complex systems and infrastructure. “Resilience of Net-Zero Energy Systems and Infrastructure: Metrics and Measurement Methods” by Mahmood Shafiee focuses on developing metrics and measurement methods for assessing the resilience of Net-Zero Energy Systems. The research aims to establish a framework for evaluating the robustness and adaptive capacity of such systems. On the other hand, “From Expert Judgment at the Early Design Stage to Quantitative Resilience Curves Using Fuzzy AHP and Dynamic Bayesian Networks” by Seyed Mojtaba Hoseyni and Joan Cordiner presents a methodological approach that transitions from expert judgment in the early design stage to the creation of quantitative resilience curves. The use of Fuzzy Analytical Hierarchy Process (AHP) and Dynamic Bayesian Networks enhances the precision and reliability of resilience assessments. Both papers underscore the importance of robust methodologies and simulation techniques in comprehensively evaluating and improving the resilience of complex energy systems and infrastructure.

3 DISCUSSION SUMMARY AND TAKEAWAY

We envisage that ETZE R3 workshop will have the following sessions:

3.1 Hydrogen Safety

The "Hydrogen Safety" session at the Risk and Resilience of Energy Transition to Net Zero Conference welcomes cutting-edge research and innovative perspectives on the safe utilization of hydrogen as a key player in the global journey toward sustainable energy solutions. As the world intensifies efforts to transition to a net-zero carbon future, the session aims to explore the challenges, advancements, and best practices associated with hydrogen safety. Papers submitted to this session may cover a wide range of topics, including but not limited to:

Hydrogen Production and Storage Safety: Addressing safety concerns related to the various methods of hydrogen production and the storage infrastructure that supports these processes. This may include advancements in technology, risk assessments, and mitigation strategies.

Transportation and Distribution Safety: Examining the safety considerations associated with the transportation and distribution of hydrogen, whether through pipelines, shipping, or other means. Papers may explore safety protocols, emergency response plans, and risk management strategies.

Hydrogen Utilization in Industry: Investigating the safety aspects of utilizing hydrogen in industrial processes, such as manufacturing and chemical production. This could involve case studies, safety guidelines, and lessons learned from real-world applications.

Hydrogen in Residential and Commercial Settings: Exploring safety protocols for the use of hydrogen in residential and commercial buildings, including fuel cells for power generation, heating, and other applications. Papers may delve into safety standards, regulatory frameworks, and public perception.

Human Factors and Behavioral Aspects: Considering the human element in hydrogen safety, including factors such as training, awareness, and the psychology of risk perception. Submissions may discuss methods to enhance safety culture and communication in the context of hydrogen technologies.

Researchers, engineers, industry professionals, and policymakers are encouraged to submit papers that contribute to the collective understanding of hydrogen safety within the broader context of the energy transition to a net-zero future. By fostering collaboration and knowledge exchange, this session aims to accelerate the safe integration of hydrogen technologies into the global energy landscape.

3.2 Wind Turbine/Farm Analysis

The "Wind Turbine/Farm Analysis" session at the Risk and Resilience of Energy Transition to Net Zero Conference invites researchers, experts, and practitioners to share their latest findings and advancements in the dynamic realm of wind energy. As the world pivots toward net-zero aspirations, wind turbines and farms play a pivotal role in the transition to sustainable energy sources. This session aims to explore the risks, resilience, and analytical strategies that contribute to the effective deployment and operation of wind energy systems. Papers submitted to this session may cover a diverse range of topics, including:

Performance and Reliability Assessment: Presenting studies that analyze the performance and reliability of wind turbines and farms, considering factors such as efficiency, maintenance strategies, and the impact of environmental conditions on long-term operation.

Technological Innovations and Design Optimization: Showcasing the latest innovations in wind turbine technology and design optimization. Papers may delve into advancements in materials, aerodynamics, and control systems aimed at enhancing efficiency and overall system resilience.

Environmental Impact and Mitigation: Exploring the environmental aspects of wind energy, including the ecological impact of wind farms on local ecosystems. Submissions may discuss strategies for minimizing the environmental footprint and enhancing the sustainability of wind energy projects.

Resilience to Extreme Weather Events: Addressing the resilience of wind energy infrastructure to extreme weather events such as hurricanes, storms, and severe temperature variations. Papers may propose engineering solutions and risk mitigation strategies to enhance the robustness of wind turbines and farms.

Integration into the Grid: Analyzing the challenges and opportunities associated with integrating wind energy into existing power grids. Submissions may discuss grid stability, energy storage solutions, and the role of wind energy in supporting a reliable and resilient power system.

Researchers and practitioners from academia, industry, and governmental organizations are encouraged to submit papers that contribute to a comprehensive understanding of the analysis, risks, and resilience associated with wind energy systems. By fostering knowledge exchange and collaboration, this session aims to accelerate the transition to a net-zero future powered by reliable, efficient, and resilient wind energy technologies.

3.3 System Level Technology Assessment

The "System Level Technology Assessment" session at the Risk and Resilience of Energy Transition to Net Zero Conference welcomes submissions that delve into the intricate landscape of energy technologies, focusing on comprehensive assessments at the system level. In the pursuit of a net-zero future, understanding the risks, resilience, and synergies among various energy technologies is paramount. This session seeks to bring together research, analyses, and insights that contribute to a holistic evaluation of energy systems, providing a roadmap for a resilient and sustainable energy transition. Papers submitted to this session may encompass a broad array of topics, including:

Integrated Energy Systems: Presenting studies that assess the performance and interplay of integrated energy systems, combining renewable sources, energy storage, and smart grids. Submissions may explore the optimization of these systems to achieve maximum efficiency and resilience.

Cross-Sectoral Synergies: Investigating synergies between different sectors such as industry, transportation, and residential areas within an overarching energy framework. Submissions may explore how cross-sectoral integration can enhance overall system resilience.

Techno-Economic Assessments: Presenting analyses that evaluate the techno-economic feasibility of various energy technologies at the system level. Papers may discuss cost-benefit analyses, financial models, and economic implications of adopting specific technology combinations.

Risk and Resilience Metrics: Introducing methodologies and frameworks for assessing the risks and resilience of energy systems. Submissions may focus on identifying vulnerabilities, developing risk mitigation strategies, and enhancing overall system robustness.

This session invites researchers, engineers, policymakers, and industry professionals to submit papers that contribute to a deepened understanding of system-level technology assessments. By fostering collaboration and knowledge sharing, the conference aims to accelerate the development of resilient and sustainable energy systems that play a pivotal role in achieving global net-zero aspirations.

3.4 Cybersecurity and Software Development

The "Cybersecurity and Software Development" session at the Risk and Resilience of Energy Transition to Net Zero Conference invites contributions that explore the critical intersection of cybersecurity and software development in the context of advancing the global energy transition. As digital technologies become integral to the infrastructure supporting net-zero goals, this session aims to address the risks, challenges, and strategies associated with securing software systems essential for the reliable and resilient operation of energy networks. Papers submitted to this session may cover a range of key topics, including:

Cyber Threat Landscape in Energy Systems: Analyzing the evolving cybersecurity threats targeting energy infrastructure, including power grids, renewable energy installations, and smart grids. Papers may offer insights into emerging cyber threats and vulnerabilities specific to the energy sector.

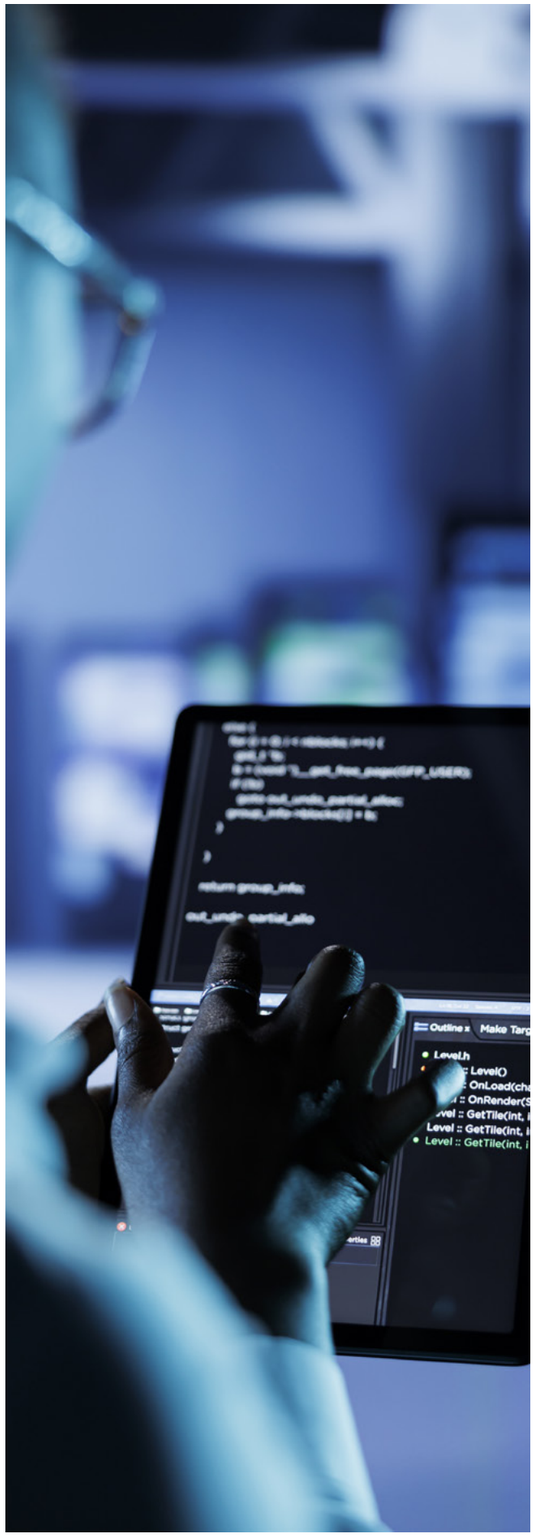
Secure Software Development Practices: Presenting methodologies, best practices, and case studies related to secure software development for energy systems. Submissions may discuss strategies for designing, coding, and maintaining software that meets high cybersecurity standards.

Resilience and Recovery Strategies: Exploring approaches to enhance the resilience of energy systems against cyber threats and outlining effective recovery strategies. Papers may discuss incident response plans, system recovery mechanisms, and lessons learned from real-world cybersecurity incidents.

IoT Security in Energy Devices: Addressing the security challenges associated with the Internet of Things (IoT) devices used in energy infrastructure. Submissions may cover secure communication protocols, device authentication, and strategies for mitigating IoT-specific cyber risks.

Human Factor in Cybersecurity: Examining the role of human factors in cybersecurity, including user awareness, training programs, and the human element in mitigating cyber risks. Submissions may discuss strategies to foster a cybersecurity-aware culture within energy organizations.

This session invites researchers, cybersecurity experts, software developers, and energy professionals to contribute papers that advance the understanding and implementation of cybersecurity measures in the context of software development for energy systems. By fostering collaboration and knowledge exchange, the conference aims to ensure the resilience and security of the digital backbone supporting the global energy transition to net-zero goals.



3.5 Regulatory Frameworks for Energy Transition

The "Regulatory" session at the Risk and Resilience of Energy Transition to Net Zero Conference provides a platform for researchers, policymakers, industry professionals, and legal experts to explore the pivotal role of regulatory frameworks in navigating the complexities of the global energy transition. As the world strives to achieve net-zero objectives, this session aims to shed light on the challenges, innovations, and best practices in energy-related regulations that facilitate a resilient and sustainable transition. Papers submitted to this session may cover a diverse range of topics, including:

Policy Innovation for Net Zero: Presenting analyses of innovative policies designed to accelerate the transition to net-zero emissions. Submissions may discuss regulatory frameworks that incentivize renewable energy adoption, energy efficiency measures, and sustainable practices across various sectors.

Regulatory Challenges in Renewable Energy Integration: Examining the regulatory hurdles associated with the integration of renewable energy sources into existing energy grids. Papers may explore strategies for overcoming barriers and optimizing regulatory structures to support a reliable and resilient renewable energy infrastructure.

Energy Market Design and Regulation: Investigating the role of market design and regulatory frameworks in fostering competition, investment, and innovation in the energy sector. Submissions may discuss market structures that encourage the deployment of sustainable technologies and the evolution of energy markets towards net-zero goals.

Cross-Border Regulatory Cooperation: Addressing the challenges and opportunities of cross-border collaboration in energy regulation. Papers may explore harmonization efforts, international standards, and regulatory frameworks that facilitate the seamless integration of sustainable energy solutions on a global scale.

Risk Mitigation through Regulations: Analyzing the ways in which regulations can be crafted to identify, assess, and mitigate risks associated with energy projects. Submissions may discuss regulatory measures that enhance the resilience of energy infrastructure against climate-related events, technological failures, or geopolitical challenges.

Regulatory Compliance and Reporting: Examining the practical aspects of regulatory compliance for energy projects. Papers may discuss reporting mechanisms, monitoring strategies, and the role of transparency in ensuring adherence to regulatory standards in the pursuit of sustainable and resilient energy solutions.

This session invites thought-provoking contributions that deepen our understanding of the intricate relationship between regulatory frameworks and the risk and resilience of energy transition initiatives. By fostering interdisciplinary dialogue and collaboration, the conference aims to shape regulatory environments that drive the global transition to a net-zero future, balancing innovation with stability and sustainability.

3.6 Modeling and Simulation Methodology

The "Modeling and Simulation Methodology" session at the Risk and Resilience of Energy Transition to Net Zero Conference invites researchers, engineers, and experts to showcase their innovative methodologies, modeling approaches, and simulation techniques that contribute to understanding and mitigating risks in the journey toward a net-zero future. In the rapidly evolving landscape of energy transition, modeling and simulation play a crucial role in assessing, predicting, and optimizing the complex interplay of technologies, policies, and environmental factors. Papers submitted to this session may span a wide spectrum of topics, including:

Integrated Energy System Modeling: Presenting advanced modeling techniques that integrate various energy vectors, such as electricity, heat, and transportation, to create comprehensive simulations of integrated energy systems. Submissions may highlight approaches that consider the dynamic interactions between different components of the energy landscape.

Climate Resilience Modeling: Addressing methodologies for modeling and simulating the impacts of climate change on energy infrastructure. Papers may explore the incorporation of climate resilience considerations into energy transition strategies, including adaptation measures and risk mitigation approaches.

Techno-Economic Modeling: Providing insights into modeling methodologies that assess the techno-economic feasibility of energy projects. Submissions may cover life cycle assessments, cost-benefit analyses, and optimization techniques to support decision-making processes in the transition to sustainable energy solutions.

Community and Stakeholder Engagement Modeling: Investigating innovative approaches to modeling community and stakeholder engagement in energy projects. Papers may discuss simulation techniques that help identify and address social and cultural factors influencing the success and acceptance of energy transition initiatives.

This session encourages papers that contribute to the methodological toolkit for understanding and managing the risks and resilience inherent in the energy transition to net-zero goals. By fostering collaboration between researchers and practitioners, the conference aims to advance the field of modeling and simulation, ultimately supporting informed decision-making and promoting the development of resilient and sustainable energy systems.

4 ORGANIZING COMMITTEE

Tarannom Parhizkar, PhD – University of California, Los Angeles

Dr. Tarannom Parhizkar is a Research Scientist at the B. John Garrick Institute for the Risk Sciences, UCLA, where she manages research projects on Energy Systems Risk and Resilience. She also holds the position of Senior Advisor within the Enterprise Risk Management Team at Southern California Edison. She holds a PhD in Energy Systems Engineering from Sharif University of Technology, Tehran, Iran. As an Energy Systems Risk Specialist, she brings a comprehensive understanding of energy infrastructures, specializing in identifying and mitigating potential risks to ensure the reliability and sustainability of diverse energy projects. With a background in modeling and simulation, she is utilizing advanced analytical tools to assess and address vulnerability, risk, and resilience in energy systems. Dr. Parhizkar expertise extends across traditional and renewable energy sources, and she is dedicated to translating complex risk analyses into actionable strategies for stakeholders and project teams. With a passion for fostering sustainability and resilience, she strives to contribute to the evolution of energy systems that are not only efficient but also environmentally conscious.

Mario P. Brito, PhD – University of Southampton

Professor Brito, a researcher in risk analysis at the intersection of statistics, science, and engineering, specializes. Notably, he contributed as a systems and dynamics engineer at BAe Systems and Stirling Dynamics from 2000 to 2005, leaving an indelible mark on projects like the A380 aircraft's manual fuel transfer system. With a Ph.D. in risk management from the University of Bristol, Prof. Brito excels in groundbreaking risk analyses, particularly for autonomous vehicles in extreme environments, with his research published in esteemed journals. Since 2015, he has been a stalwart at the University of Southampton, leading the validation of the MSc in Risk Management and serving as MSc Programme leader. As a dedicated educator, he imparts knowledge in Project Risk Management and Quantitative Methods for Risk Management. In addition to his academic roles, Professor Brito holds the distinguished position of Head of the Department of Decision Analysis & Risk at the Southampton Business School. A member of prestigious academic and industry societies, he contributes to the ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems and notably served as the General Chairman of the 33rd European Safety and Reliability Conference in Southampton. Moreover, he acts as an external examiner for the BSc Honours in Risk Management at the University of Caledonia.

ESREL 2023 PARTICIPANTS

Participant	Affiliation
Abera Hailu Mewcha	Sporveien, Norway.
Abhishek Subedi	Department of Mechanical Engineering, Kathmandu University, Nepal.
Alessandro Campari	Department of Mechanical and Industrial Engineering, NTNU, Norway
Alexander Gabrielb	Department for Resilience of Maritime Systems, Institute for the Protection of Maritime Infrastructures, German Aerospace Center (DLR), Germany
Alexandre Sheremetieff	Department of Engineering, Universidade Católica de Petrópolis, Brazil
Ali Nawaz	School of Mechanical and Electrical Engineering, University of Electronic Science and Technology of China. Center for System Reliability and Safety, University of Electronic Science and Technology of China, Chengdu, Sichuan, P.R. China. Department of Mechanical Engineering, MUET SZAB Campus Khairpur Mir's, Pakistan.
Alice Schiaroli	Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, Italy. Department of Mechanical and Industrial Engineering, NTNU, Norway
Antonio Alvaro	SINTEF Industry, SINTEF, Norway.
Arto Niemi	German Aerospace Center (DLR), Institute for the Protection of Maritime Infrastructures, Germany.
Asgeir Drøivoldsmo	Digital Systems, IFE, Norway.
Babette Tecklenburga	Department for Resilience of Maritime Systems, Institute for the Protection of Maritime Infrastructures, German Aerospace Center (DLR), Germany
Baptiste Bougoüina	TotalEnergies, Pau, France
Bartosz Skobiej	German Aerospace Center (DLR), Institute for the Protection of Maritime Infrastructures, Germany.
Biraj Singh Thapa	Department of Mechanical Engineering, Kathmandu University, Nepal
Carlos Eduardo Cardoso de Souzaa	Department of Engineering, Universidade Católica de Petrópolis, Brazil
Dana Prochazkova	Czech Technical University in Prague, Technicka 4, 166 00 Praha 6, Czech Republic.
Diletta Ferrazzano	Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, Italy
Dong Won Lee	Severe Accident & Risk Assessment/KINS, South Korea.
Eivind Halvard Okstad	SINTEF Digital, Norway.
Eleftherios Siskos	Laboratory for Energy Systems Analysis, Paul Scherrer Institute (PSI), Villigen PSI, Switzerland.
Elena Stefana	Department of Mechanical and Aerospace Engineering, Sapienza University of Rome, Italy.

Participant	Affiliation
Federico Ustolin	Department of Mechanical and Industrial Engineering, NTNU, Norway.
Frank Sill Torres	Department for Resilience of Maritime Systems, Institute for the Protection of Maritime Infrastructures, German Aerospace Center (DLR), Germany
Gerard Stapleton	Electricity Supply Board, Hydrogen Lighthouse project, Ireland.
Giordano Emrys Scarponi	Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, Italy.
Guillaume Clémentc	TotalEnergies, Pau, France.
Hao Liu	College of Safety and Ocean Engineering, China University of Petroleum (Beijing), China.
Hector Diego Estrada-Lugo	Human Factors in Safety and Sustainability Research group, Technological University Dublin, Ireland.
Hong-Zhong Huang	School of Mechanical and Electrical Engineering, University of Electronic Science and Technology. Center for System Reliability and Safety, University of Electronic Science and Technology of China, Chengdu, Sichuan, P.R. China.
Hyonjeong Noh	Korea Research Institute of Ships and Ocean Engineering, Geoje-si, Korea.
Jan Prochazka	Q-media s.r.o., Pocernická 272/96, 10800 Praha 10, Czech Republic

Participant	Affiliation
Janne Hagen	Institute of Informatics, University of Oslo, Norway.
Jens Kahlen	German Aerospace Center (DLR), Institute for the Protection of Terrestrial Infrastructures, Germany.
Joan Cordinerb	Department of Chemical and Biological Engineering, The University of Sheffield, UK.
Jon-Martin Storma	Institute of Informatics, University Of Oslo, Norway.
José Cristiano Pereirac	Department of Engineering, Universidade Católica de Petrópolis, Brazil.
Juan Sun	Service de Métrologie Nucléaire, Université libre de Bruxelles, Belgium.
Karin Bernsmed	SINTEF Digital, Norway.
Karoline Pelka	Fraunhofer Institute for Wind Energy Systems IWES, Germany.
Katharina Fischer	Fraunhofer Institute for Wind Energy Systems IWES, Germany.
Kwangu Kang	Korea Research Institute of Ships and Ocean Engineering, Geoje-si, Korea.
Laibin Zhang	College of Safety and Ocean Engineering, China University of Petroleum (Beijing), China.
Lars Halvdan Flå	SINTEF Digital, Norway.
Lars Hurlena	Digital Systems, IFE, Norway.
Louise Roe	Electricity Supply Board, Hydrogen Lighthouse project, Ireland.
Lukas Halekotte	German Aerospace Center (DLR), Institute for the Protection of Terrestrial Infrastructures, Germany.
Mahmood Shafiee	School of Mechanical Engineering Sciences, University of Surrey, Guildford GU27XH, UK.
Maïder Estécahandyb	TotalEnergies, Pau, France
Maria Chaira Leva	Human Factors in Safety and Sustainability Research group, Technological University Dublin, Ireland.
Mario P. Brito	University of Southampton
Matteo Spada	Institute of Sustainable Development, Zurich University of Applied Sciences, Winterthur, Switzerland.
Nicola Paltrinieri	Department of Mechanical and Industrial Engineering, NTNU, Norway
Nikolai Kulev	German Aerospace Center (DLR), Institute for the Protection of Maritime Infrastructures, Germany.
Panikkar, Sujith Bhaskara	HIMA, Australia.
Peter Burgherr	Laboratory for Energy Systems Analysis, Paul Scherrer Institute, Villigen PSI, Switzerland.
Petr Novobilsky	Q-media s.r.o., Pocernická 272/96, 10800 Praha 10, Czech Republic
Pierre-Etienne Labeau	Service de Métrologie Nucléaire, Université libre de Bruxelles, Belgium.
Qingqing Xu	College of Safety and Ocean Engineering, China University of Petroleum (Beijing), China.

Participant	Affiliation
Raquel Machado Gomesb	Department of Engineering, Universidade Católica de Petrópolis, Brazil
Rebecca Lordan-Perret	Energy Economics, University of Basel, Basel, Switzerland.
Robert Bains	SINTEF Digital, Norway.
Russell McKenna	Laboratory for Energy Systems Analysis, Paul Scherrer Institute (PSI), Villigen PSI, Switzerland.
Sadiq. Ali. Shah	Department of Mechanical Engineering, MUET SZAB Campus Khairpur Mir′s, Pakistan.
Sajawal Gul Niazi	School of Mechanical and Electrical Engineering, University of Electronic Science and Technology of China. Center for System Reliability and Safety, University of Electronic Science and Technology of China, Chengdu, Sichuan, P.R. China. Department of Mechanical Engineering, MUET SZAB Campus Khairpur Mir's, Pakistan.
Seyed Mojtaba Hoseynia	Department of Chemical and Biological Engineering, The University of Sheffield, UK.
Sharmin Sultana	DynSoL AS.
Siang Meng Sin, Ivan	National University of Singapore, Singapore.
Sinead Treanor	Electricity Supply Board, Hydrogen Lighthouse project, Ireland.
Siyuan Liu	National University of Singapore, Singapore.
Taotao Zhou	College of Safety and Ocean Engineering, China University of Petroleum (Beijing), China.
Tarannom Parhizkar	University of California, Los Angeles
Tobias Demmer	German Aerospace Center (DLR), Institute for the Protection of Terrestrial Infrastructures, Germany.
Tudi Huang	School of Mechanical and Electrical Engineering, University of Electronic Science and Technology of China. Center for System Reliability and Safety, University of Electronic Science and Technology of China, Chengdu, Sichuan, P.R. China.
Tzu Yang Loh	National University of Singapore, Singapore.
Valerio Cozzani	Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, Italy
Yingchun Ye	College of Safety and Ocean Engineering, China University of Petroleum (Beijing), China.
Youngkyun Seo	Korea Research Institute of Ships and Ocean Engineering, Geoje-si, Korea.

ATTACHMENT A

Hydrogen-related Safety:

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6. Requirements for quantitative risk assessment of hydrogen facilities: An Irish use case (Hector Diego Estrada-Lugo, Maria Chaira Leva, Sinead Treanor, Gerard Stapleton, Louise Roe) - P349
7. Risk management at various stages of project management of a Hydrogen facility (Sharmin Sultana) - P671
8. Numerical modelling of liquid hydrogen tanks performance during fire engulfment (Alice Schiaroli, Giordano Emrys Scarponi, Valerio Cozzani, Federico Ustolin) - P427

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