5TH SEE CONFERENCE ON SUSTAINABLE DEVELOPMENT OF ENERGY, WATER AND ENVIRONMENT SYSTEMS

May, 22-26, 2022
Vlorë, Albania

BOOK OF ABSTRACTS

Edited by:
Marko Ban, Neven Duić, Aleksandra Anić Vučinić, Jakov Baleta, Yee Van Fan, Konalsi Gjoka, Skender Kabashi, Jiří Jaromír Klemeš, Gazmend Pula, Petar Sabev Varbanov, Milan Vujanović

sdewes
INTERNATIONAL CENTRE FOR SUSTAINABLE DEVELOPMENT OF ENERGY, WATER AND ENVIRONMENT SYSTEMS

5th SOUTH EAST EUROPEAN CONFERENCE ON SUSTAINABLE DEVELOPMENT OF ENERGY, WATER AND ENVIRONMENT SYSTEMS

BOOK OF ABSTRACTS

May 22 – 26, 2022, Vlorë, Albania

Organizers

University of Zagreb, Zagreb, Croatia
Instituto Superior Técnico, Lisbon, Portugal
University of Tirana, Tirana, Albania
University of Vlora "Ismail Qemali", Vlora, Albania

In cooperation with

Aalborg University, Aalborg, Denmark
American International College, Saad Al-Abdullah, Kuwait
University of Belgrade, Belgrade, Serbia
Brno University of Technology, Brno, Czech Republic
Universidad de Buenos Aires, Buenos Aires, Argentina
Cyprus University of Technology, Limassol, Cyprus
TH Köln – University of Applied Sciences, Cologne, Germany
Delft University of Technology, Delft, The Netherlands
University of Dubrovnik, Dubrovnik, Croatia
Hamburg University of Applied Sciences, Hamburg, Germany
Jozef Stefan International Postgraduate School, Ljubljana, Slovenia
Macedonian Academy of Sciences and Arts, MASA-RCESD, Skopje, Macedonia
University of Palermo, Palermo, Italy
American University of Ras Al Khaimah, Ras Al-Khaimah, United Arab Emirates
Federal University of Rio de Janeiro, Rio de Janeiro, Brazil
Industrial University of Santander, Bucaramanga, Colombia
University of Sarajevo, Sarajevo, Bosnia and Herzegovina
The Scientific and Technological Research Council of Turkey (TÜBİTAK), Ankara, Turkey
"Vinča" Institute of Nuclear Sciences, Belgrade, Serbia
Warsaw University of Technology, Warsaw, Poland
Xi'an Jiaotong University, Xi'an, Shaanxi, China

Executive organizers

International Centre for Sustainable Development of Energy, Water and Environment Systems, Zagreb, Croatia
Croatian Energy Transition, Zagreb, Croatia

Partners

The Combustion Institute – Adria Section, Zagreb, Croatia
Slovenian Association for the Club of Rome, Ljubljana
Club of Rome - European Research Centre, Konstanz
Mediterranean Network for Engineering Schools and Technical Universities – RMEI, Marseille, France
The World Academy of Art and Science

BASIC SPONSORS

International Scientific Committee

Prof. Maria da Graça Carvalho, Instituto Superior Técnico, Lisbon, Portugal, Chair
Prof. Neven Duic, University of Zagreb, Zagreb, Croatia, Co-chair
Prof. Jiří Jaromír Klemeš, Brno University of Technology - VUT Brno, Brno, Czech Republic, Co-Chair for the Central and Eastern Europe
Prof. Henrik Lund, Aalborg University, Aalborg, Denmark, Co-Chair for Northern Europe
Prof. Ingo Stadler, TH Köln, Cologne, Germany, Co-Chair for Western Europe
Prof. Poul Alberg Østergaard, Aalborg University, Aalborg, Denmark
Prof. Susana Boeykens, Universidad de Buenos Aires, Buenos Aires, Argentina
Prof. Annamaria Buonomano, University of Naples Federico II, Napoli, Italy
Prof. Francesco Calise, University of Naples Federico II, Naples, Italy
Prof. Raf Dewil, KU Leuven, Leuven, Belgium
Prof. Zvonimir Guzović, University of Zagreb, Zagreb, Croatia
Dr. Şiir Kilkiş, The Scientific and Technological Research Council of Turkey (TÜBİTAK), Ankara, Turkey
Prof. Soteris Kalogirou, Cyprus University of Technology, Limassol, Cyprus
Prof. Tarik Kupusovic, University of Sarajevo, Sarajevo, Bosnia and Herzegovina
Prof. Natasa Markovska, Macedonian Academy of Sciences and Arts, Skopje, North Macedonia
Prof. Brian Vad Mathiesen, Aalborg University, Aalborg, Denmark
Prof. Mousa Mohsen, American International College, Kuwait
Prof. Adolfo Palombo, University of Naples Federico II, Naples, Italy
Prof. Antonio Piacentino, University of Palermo, Palermo, Italy
Prof. Nikola Rajakovic, University of Belgrade, Belgrade, Serbia
Prof. Nikola Ruzinski, University of Zagreb, Zagreb, Croatia
Prof. Eduardo Serra, Universidade Federal do Rio de Janeiro – UFRJ, Rio de Janeiro, Brazil
Prof. Daniel Rolph Schneider, University of Zagreb, Zagreb, Croatia
Prof. Rodney Stewart, Griffith University, Gold Coast City, Australia
Prof. Ivo Šlaus, Rudjer Boskovic Institute, Zagreb, Croatia
Prof. Krzysztof Urbaniec, Warsaw University of Technology, Plock, Poland
Dr. Petar Sabev Varbanov, Brno University of Technology - VUT Brno, Brno, Czech Republic
Prof. Qiuwang Wang, Xi'an Jiaotong University, Xi'an, Shaanxi, China
Prof. Jinyue Yan, Royal Institute of Technology, Stockholm, Sweden
Prof. Aleksander Zidanšek, Jozef Stefan International Postgraduate School, Ljubljana, Slovenia

Honorary members
Prof. Kemal Hanjalic, Delft University of Technology, Delft, Netherlands
Prof. Vyacheslav Kafarov, Industrial University of Santander, Bucaramanga, Colombia
Prof. Walter Leal Filho, Hamburg University of Applied Sciences, Hamburg, Germany
Prof. Vladimir Lipovac, University of Dubrovnik, Dubrovnik, Croatia, honorary member
Prof. Simeon Oka, Institute Vinca, Novi Beograd, Belgrade, Serbia
Prof. Jordan Pop-Jordanov, Macedonian Academy of Sciences and Arts, Skopje, Macedonia
Dr. Subhas K. Sikdar, United States Environmental Protection Agency, Cincinnati, United States
Prof. Xiliang Zhang, Tsinghua University, Beijing, China

Local Organizing Committee

Prof. Kledi Xhaxhiu, University of Tirana, CHAIR
Prof. Neven Duic, University of Zagreb, CO-CHAIR
Prof. Elda Marku, University of Tirana, CO-CHAIR
Prof. Zvonimir Guzović, University of Zagreb, Conference secretary
Prof. Naser Sahiti, University of Prishtina „Hasan Prishtina", Rector
Prof. Besnik Baraj, Faculty of Natural Sciences
Prof. Flora Qarri, University of Vlora
Prof. Alajdin Abazi, Macedonian Academu of Sciences an Arts - MANU
Prof. Arjan Korpa, University of Tirana
Prof. Edmond Zeneli, Polytechnic University of Tirana
Prof. Sajmir Beqiraj, University of Tirana
Dr. Marko Ban, SDEWES Centre
Dr. Tomislav Pukšec, University of Zagreb
Mr. Tibor Bešenić, University of Zagreb
Ms. Andreja Biskup Lazanin, SDEWES Centre
Mr. Hrvoje Dorotić, University of Zagreb
Mr. Luka Herc, University of Zagreb
Ms. Nensi Isak, Faculty of Natural Sciences, University of Tirana
Mr. Filip Jurić, University of Zagreb
Ms. Ana-Marija Ljubanovic, SDEWES Centre
Ms. Ana Lovrak, University of Zagreb
Prof. Ilirjan Malollari, University of Tirana
Mr. Marijan Marković, University of Zagreb, Croatia
Mr. Josip Miškić, University of Zagreb
Mr. Marko Mimica, University of Zagreb
Ms. Zvjezdana Nađ Dujmović, SDEWES Centre
Mr. Antun Pfeifer, University of Zagreb
Mr. Dusko Stajic, SDEWES Centre
Mr. Goran Stunjek, University of Zagreb

Publisher Faculty of Mechanical Engineering and Naval Architecture, Zagreb

ISSN – 2706-3682 (digital proceedings)

Editors

Marko Ban
Neven Duić
Aleksandra Anić Vučinić
Jakov Baleta
Yee Van Fan
Konalsi Gjoka
Skender Kabashi
Jiří Jaromír Klemeš
Gazmend Pula
Petar Sabev Varbanov
Milan Vujanović

Technical Editors Aleksandra Mudrovčić, Marko Ban

Scientific Advisory Board

I. **Šlaus**, *Croatia* - Chairman

J. **Adiansyah** , Indonesia; E. **Ahmetović** , Bosnia and Herzegovina; A. **Ajanovic** , Austria; S. **Ajib** , Germany; F. **Al-Mansour** , Slovenia; S. **Alabrudzinski** , Poland; A.H. **Alami** , United Arab Emirates; A. **Alami Merrouni** , Morocco; D.M. S. **Albuquerque** , Portugal; M. **Alcani** , Albania; M. **Alfe** , Italy; A. **Almutairi** , Kuwait; A. **Alouache** , Algeria; A. **Altmimi** , Iraq; P. **Ammendola** , Italy; A. **Anastasovski** , North Macedonia; A. **Anić Vučinić** , Croatia; S. **Anweiler** , Poland; E. **Apaydın Varol** , Turkey; D. **Astiaso Garcia** , Italy; S. **Atabay** , United Arab Emirates; A. **Avami** , Iran; S. **Avdullahi** , Kosovo; J. **Avsec** , Slovenia; M.I. **Ayala Chauvin** , Ecuador; P. **Škobalj** , Serbia; B. **Škrbić** , Serbia; R. **Šomplák** , Czech Republic; V. **Šušteršič** , Serbia; A. **Žnidarčič** , Slovenia; Z. **Čepić** , Serbia; R. **Černý** , Czech Republic; L. **Čuček** , Slovenia; M. **Ćalasan** , Montenegro; C. **Baglivo** , Italy; A. **Baldinelli** , Italy; G. **Bandov** , Croatia; B. **Baraj** , Albania; S.S. **Baral** , India; G. **Barone** , Italy; I. **Barut** , Turkey; I. **Batas Bjelic** , Serbia; T. **Bešenić** , Croatia; M. **Beccali** , Italy; J.A. **Becerra Villanueva** , Spain; S. **Bekteshi** , Kosovo; E. **Bellos** , Greece; U. **Berardi** , Canada; V. **Bermudez Benito** , Qatar; D. **Beysens** , France; R. **Bhandari** , Germany; F. **Bidaj** , Albania; M. **Bietresato** , Italy; J. **Bogdanović-Jovanović** , Serbia; S. **Boldyryev** , Croatia; J. **Bonet-Ruiz** , Spain; M. **Bonomolo** , Italy; S.P. **Borg** , Malta; D. **Boskovska** , North Macedonia; P. **Brachi** , Italy; T.A. **Branca** , Italy; R.M. **Brito Alves** , Brazil; J.K. **Calautit** , United Kingdom; C. **Caligiuri** , Italy; P. **Canciani** , Italy; F.L. **Cappiello** , Italy; T. **Capuder** , Croatia; P. **Caputo** , Italy; N. **Caracciolo** , Argentina; F. **Cardona** , Italy; R. **Carli** , Italy; M. **Carvalho** , Brazil; B. **Castellani** , Italy; P. **Catrini** , Italy; J. **Cerezo** , Mexico; G. **Cerri** , Italy; B. **Cestnik** , Slovenia; R. **Chacartegui** , Spain; F. **Chang** , Taiwan; M. **Charde** , United Arab Emirates; P. **Charvat** , Czech Republic; D. **Chemisana** , Spain; B.L.F. **Chin** , Malaysia; D. **Chinese** , Italy; G. **Cinti** , Italy; M. **Cipek** , Croatia; A. **Cormos** , Romania; C. **Cormos** , Romania; M. **Correia De Oliveira** , Portugal; N. **Cukovic Ignjatovic** , Serbia; U. **Cvelbar** , Slovenia; D. **Cvetinović** , Serbia; S. **Cvetkovic** , Serbia; D. **D'agostino** , Italy; M. **Dabic** , Croatia; N. **Daniloska** , North Macedonia; G. **Danon** , Serbia; G. **Davis** , United States; I. **Džijan** , Croatia; M. **Dębowski** , Poland; C. **De Blasio** , Finland; A. **De Pascale** , Italy; S.N. **De Souza** , Brazil; A. **Dedinec** , North Macedonia; N. **Degiuli** , Croatia; M. **Despotovic** , Serbia; S. **Di Fraia** , Italy; A. **Di Maria** , Belgium; F.B. **Dilek** , Turkey; C. **Dinca** , Romania; O. **Dogerlioglu Isiksungur** , Turkey; J. **Domac** , Croatia; D.F. **Dominković** , Denmark; D. **Dović** , Croatia; D. **Drazic** , Serbia; E. **Duarte** , Portugal; E. **Dzaferovic** , Bosnia and Herzegovina; M. **Dzikuć** , Poland; A. **Egusquiza** , Spain; R. **El-Emam** , Canada; A. **Elshkaki** , China; V. **Eveloy** , United Arab Emirates; B. **Fabiano** , Italy; Y.V. **Fan** , Czech Republic; F. **Feijoo** , Chile; S. **Ferrari** , Italy; J. **Ferreira** , Portugal; L. **Fiala** , Czech Republic; R. **Figaj** , Poland; O. **Filho** , Brazil; V. **Filipan** , Croatia; S. **Filipović** , Serbia; M. **Filipowicz** , Poland; R.V. **Filkoski** , North Macedonia; K.F.S. **Fong** , China; D. **Foo** , Malaysia; C. **Forzano** , Italy; V. **Franzitta** , Italy; F. **Freire** , Portugal; A. **Gagliano** , Italy; A. **Galinis** , Lithuania; M.T. **García-Álvarez** , Spain; N. **Gaurina-Međimurec** , Croatia; A. **Göllei** , Hungary; M. **Genovese** , Italy; M. **Georgiadis** , Greece; A. **Gholamzadeh Chofreh** , Czech Republic; A. **Gholamzadeh Chofreh** , Czech Republic; A. **Gianfreda** , Italy; D. **Giannakopoulos** , Greece; A. **Gomes** , Portugal; F. **Gonella** , Italy; A. **González-Espinosa** , Spain; D. **Gordic** , Serbia; D. **Goricanec** , Slovenia; W. **Goryl** , Poland; L. **Greco** , Italy; F. **Guarino** , Italy; X. **Guo** , China; L. **Gustavsson** , Sweden; Z. **Gviniashvili** , Georgia; B. **Gvozdenac Urosevic** , Serbia; D.L. **Ha** , France; R. **Haas** , Austria; A. **Haddad** , Brazil; S. **Halilčević** , Bosnia and Herzegovina; M.I. **Hassan Ali** , United Arab Emirates; M. **Hájek** , Czech Republic; P. **Hendrick** , Belgium; E. **Henning** , Brazil; C. **Henriques** , Portugal; M. **Herrando** , Spain; I. **Herrera** , Spain; N. **Holjevac** , Croatia; H. **Hondo** , Japan; M. **Honic** , Austria; A.K. **Hossain** , United Kingdom; W. **Huang** , Taiwan; J. **Hur** , Korea, Republic of; F. **Hvelplund** , Denmark; P. **Iglecias** , Brazil; V. **Ivanovic** , Poland; D. **Ivezic** , Serbia; T. **Izumi** , Japan; D. **Jakus** , Croatia; V. **Józsa** , Hungary; B. **Jiang** , China; A. **Jovovic** , Serbia; D. **Juchelkova** , Czech Republic; S. **Kabashi** , Kosovo; S. **Kabashi** , Kosovo; M. **Kacprzak** , Poland; E. **Kakaras** , Greece; S. **Kambara** , Japan; I. **Karabegović** , Bosnia and Herzegovina; D. **Karasalihović Sedlar** , Croatia; M. **Kassai** , Hungary; A. **Kazagic** , Bosnia and Herzegovina; A.R. **Keeley** , Japan; M. **Keppert** , Czech Republic; H. **Keskin Citiroglu** , Turkey; A. **Khosravi** , Finland; T. **Kienberger** , Austria; B. **Kilkis** , Turkey; Y. **Kim** , Korea, Republic of; V. **Kirincic** , Croatia; D. **Klimenta** , Serbia; J. **Knápek** , Czech Republic; M.

Knez , Slovenia; C. **Ko** , Taiwan; S. **Koščak Kolin** , Croatia; D. **Koncalovic** , Serbia; K. **Kontoleon** , Greece; A. **Korpa** , Albania; R. **Kovačič Lukman** , Slovenia; G. **Krajačić** , Croatia; A. **Krkoleva** , North Macedonia; G. **Krolczyk** , Poland; P. **Krstevski** , North Macedonia; H. **Krstic** , Croatia; J. **Krstivojevic** , Serbia; L. **Kulay** , Brazil; S. **Lajqi** , Kosovo; G. **Lazaroiu** , Romania; L. **Lešnik** , Slovenia; K.T. **Lee** , Malaysia; A. **Lefkir** , Algeria; V. **Lekavičius** , Lithuania; Y. **Li** , China; T.C. **Ling** , Malaysia; A. **Liu** , Australia; G. **Liu** , China; X. **Liu** , Denmark; S. **Lohani** , Nepal; D. **Lončar** , Croatia; A.G. **Lopes** , Portugal; N.S. **Lopez** , Philippines; J. **Louis** , Finland; M. **Lu** , Taiwan; T. **Ma** , China; M. **Majidi Nezhad** , Italy; A. **Makarova** , Russian Federation; I. **Malico** , Portugal; L. **Malka** , Albania; I. **Malollari** , Albania; M.L. **Maloncy** , Netherlands; N. **Manic** , Serbia; A. **Maraj** , Albania; C.N. **Markides** , United Kingdom; E. **Marku** , Albania; E. **Marrasso** , Italy; L. **Martinelli** , Italy; B. **Martinkauppi** , Finland; F.V. **Matera** , Italy; N. **Matera** , Italy; I. **Mauleón** , Spain; P. **Maussion** , France; G. **Mavromatidis** , Switzerland; D. **Mazzeo** , Italy; A. **Mazzi** , Italy; B. **Möller** , Germany; M. **Münster** , Denmark; R. **Medronho** , Brazil; T. **Mehmood** , China; I. **Mehrotra** , India; D. **Menegon** , Italy; H. **Meschede** , Germany; H. **Mikulčić** , Croatia; M. **Mistretta** , Italy; M. **Mistretta** , Italy; M. **Moldovan** , Romania; J. **Mondol** , United Kingdom; L. **Montorsi** , Italy; J. **Moravcová** , Czech Republic; M. **Mori** , Slovenia; M. **Muccillo** , Italy; B. **Nakomčić-Smaragdakis** , Serbia; F. **Nardecchia** , Italy; B. **Nastasi** , Italy; M. **Neagoe** , Romania; A.M. **Negm** , Egypt; S. **Nižetić** , Croatia; Y. **Noorollahi** , Iran; M. **Noro** , Italy; B. **Norton** , Ireland; R. **Norvaišienė** , Lithuania; N. **Novelli** , United States; M. **Obrecht** , Slovenia; C.M. **Odulio** , Philippines; K.Y. **Oh** , Korea, Republic of; T. **Okadera** , Japan; M. **Olazar** , Spain; H.C. **Ong** , Taiwan; S. **Padula** , Italy; C. **Pak** , Korea, Republic of; T. **Palander** , Finland; H. **Pandžić** , Croatia; A. **Pantaleo** , Italy; E. **Paris** , Italy; Y. **Park** , Korea, Republic of; G. **Pasternak** , Poland; D. **Pavkovic** , Croatia; M. **Pavlas** , Czech Republic; J. **Pedraza Garciga** , Cuba; J. **Peralta Jaramillo** , Ecuador; Y. **Peralta-Ruiz** , Colombia; A. **Pereira** , Brazil; P. **Pereira Da Silva** , Portugal; T. **Petkovska Mircevska** , North Macedonia; V. **Petkovski** , North Macedonia; F. **Petrakopoulou** , Spain; Z. **Petranović** , Austria; A. **Pfeifer** , Croatia; F. **Pietrapertosa** , Italy; C. **Piselli** , Italy; A. **Piwowar** , Poland; A.E. **Plesu Popescu** , Spain; J.M. **Ponce-Ortega** , Mexico; N. **Popov** , Canada; S. **Postoronca** , Moldova; F. **Prado Jr.** , Brazil; H. **Pramanik** , India; D.. A. **Predin** , Slovenia; D. **Pretolani** , Italy; M.G. **Prina** , Italy; L. **Proskuryakova** , Russian Federation; M. **Protic** , Serbia; T. **Pukšec** , Croatia; M. **Pusnik** , Slovenia; F. **Qarri** , Albania; S. **Quoilin** , Belgium; F. **Raganati** , Italy; A.M. **Ragossnig** , Austria; B. **Rajh** , Slovenia; J. **Ramos** , Portugal; P. **Raskovic** , Serbia; L. **Razon** , Philippines; L. **Režný** , Czech Republic; C. **Ribeiro** , Brazil; F. **Rinaldi** , Italy; F. **Rizzi** , Italy; J. **Rodríguez Martín** , Spain; A. **Rodzkin** , Belarus; G. **Romano** , Italy; C. **Roselli** , Italy; V. **Roy** , France; J.E. **Ruelas Ruiz** , Mexico; A. **Runchal** , United States; E. **Rusu** , Romania; L. **Rusu** , Romania; T. **Ryley** , Australia; O. **Sahin** , Australia; N. **Sahiti** , Kosovo; I. **Sakata** , Japan; M. **Salvia** , Italy; N. **Samec** , Slovenia; M.. **San-Román** , Spain; C. **Sarasa** , Spain; C. **Sarasa** , Spain; M. **Sarmento** , Portugal; I. **Savic** , Serbia; I. **Savic Gajic** , Serbia; A. **Savvides** , Cyprus; M. **Schiemann** , Germany; H. **Schlör** , Germany; J. **Schmandt** , United States; T. **Schneiders** , Germany; V. **Sebestyén** , Hungary; R. **Segurado** , Portugal; M. **Sellitto** , Brazil; A. **Siirde** , Estonia; N. **Simões** , Portugal; S. **Singh** , India; M. **Siroux** , France; I.R. **Skov** , Denmark; S. **Sofia Ferreira Da Silva Caeiro** , Portugal; L. **Sokka** , Finland; V. **Soldo** , Croatia; R. **Solimene** , Italy; V. **Somogyi** , Hungary; M.- L. **Soran** , Romania; A. **Soria Verdugo** , Spain; P. **Sorknæs** , Denmark; K. **Sornek** , Poland; J. **Sousa** , Portugal; L. **Sphaier** , Brazil; M. **Srbinovska** , North Macedonia; S. **Stanković** , Serbia; P. **Stefanović** , Serbia; Ž. **Stevanović** , Serbia; M. **Stojiljković** , Serbia; D. **Stojiljkovic** , Serbia; B. **Sucic** , Slovenia; S.A. **Sulaiman** , Malaysia; B. **Sundén** , Sweden; K. **Suwannahong** , Thailand; P. **Swiatek** , Germany; C. **Sy** , Philippines; T. **Tabata** , Japan; L.C. **Tagliabue** , Italy; J. **Taler** , Poland; A. **Tamosiunas** , Lithuania; V. **Taseska-Gjorgievska** , North Macedonia; V. **Tasić** , Serbia; M.D. **Tenev** , Argentina; A. **Terelak-Tymczyna** , Poland; J. **Terrados Cepeda** , Spain; A. **Terziev** , Bulgaria; E. **Tesfamariam** , South Africa; J. **Thakur** , Sweden; G.M. **Tina** , Italy; T. **Tomić** , Croatia; Z. **Tomsic** , Croatia; M. **Trafczynski** , Poland; M. **Trajanović** , Serbia; K.C. **Tran - Gulbrandsen** , Norway; G. **Trbic** , Bosnia and Herzegovina; C. **Tregambi** , Italy; M. **Trninic** , Serbia; L. **Tronchin** , Italy; A. **Tskhai** , Russian Federation; V. **Tunguz** , Bosnia and Herzegovina; J. **Uche** , Spain; W. **Uchman** , Poland; G. **Unakitan** , Turkey; K. **Unami** , Japan; A. **Vakhitov** , Uzbekistan; F. **Valencia** , Chile; L. **Vanoli** , Italy; Z. **Varga** , Hungary; G. **Vasic** , Serbia; C. **Vassiliades** , Cyprus; S. **Vasta** , Italy; V.K. **Venkiteswaran** , Malaysia; M. **Vicidomini** , Italy; M. **Villarini** , Italy; A. **Viskovic** , Croatia; R. **Volpe** , Italy; G. **Vučković** , Serbia; I. **Vušanović** , Montenegro; I. **Vušanović** , Montenegro; B. **Vucijak** , Bosnia and Herzegovina; R. **Vujadinovic** , Montenegro; M. **Vujanović** , Croatia; V. **Vukasinovic** , Serbia; V. **Vukovic** , North Macedonia; T. **Walmsley** , New Zealand; S.R. **Wan Alwi** , Malaysia; E. **Wang** , United States; F. **Wang** , China; J. **Wang** , China; M. **Webb** , Australia; S. **Werle** , Poland; D. **Wittmann** , Brazil; K. **Wołosz** , Poland; S. **Wongcharee** , Thailand; K. **Xhaxhiu** , Albania; K. **Xhaxhiu** , Albania; D. **Xia** , China; H.A. **Yavasoglu** , Turkey; U. **Yetis** , Turkey; C. **Yin** , Denmark; F. **You** , United States; O. **Zavalani** , Albania; B. **Zhang** , China; X. **Zhang** , China; X. **Zhang** , China;

D. **Zivkovic** , Serbia; P. **Zivkovic** , Serbia; H. **Zou** , China; P. **Zunino** , Italy; G.D. **Zupančič** , Croatia; K. **Zwarycz-Makles** , Poland

Conference Venue: Vlorë

The town of Vlorë is the third most populous city of the Republic of Albania and seat of Vlorë County and Vlorë Municipality. Located in southwestern Albania, Vlorë sprawls on the Bay of Vlorë and is surrounded by the foothills of the Ceraunian Mountains along the Albanian Adriatic and Ionian Sea Coasts. It experiences a Mediterranean climate, which is affected by the Ceraunian Mountains and the proximity to the Mediterranean Sea.

Vlorë was founded as Aulon as an Ancient Greek colony on the Illyrian coast and was conquered at different periods throughout history by Romans, Byzantines, Normans, Venetians and Ottomans. Between the 18th and 19th centuries, the Albanians gathered both spiritual and intellectual strength for national consciousness, which conclusively led to the Albanian Renaissance. Vlorë played an instrumental role in Albanian Independence as an epicenter for the founders of modern Albania, who signed the Declaration of Independence on 28 November 1912 at the Assembly of Vlorë.

Vlorë is one of the most significant cities of southern Albania and the region of Labëria which is traditionally noted for its culture, traditions and folklore. Vlorë is served by the Port of Vlorë, the SH8 highway, and the A2 motorway, collectively representing part of the Adriatic–Ionian Corridor and the Pan-European Corridor VIII.

The diversity of its territory makes Vlorë a city for everyone, from the mountains in the Llogara National Park, to the Riviera, from the narrow alleys of the historic city-center to the various archaeological sites.

Scope and Objectives

The main challenge for South East Europe (SEE) economies is to commit to, and sustain the implementation of, long-term reforms aimed at increasing competitiveness and promoting sustainable, inclusive and balanced development, as well as better integration between the EU Member States, candidate and potential candidate countries and neighbouring countries. An adequate response to this challenge will certainly require using the best available scientific knowledge and constant re-evaluation of the development process in light of the scientific findings. Therefore, it will be essential to enhance the scientific understanding, improve the long-term scientific assessments, strengthen the scientific capacities and ensure that the sciences are responsive to the emerging needs.

> "History teaches us that men and nations behave wisely once they have exhausted all other alternatives"
>
> *Abba Eban*

Along this line, a regional series of biannual Sustainable Development of Energy Water and Environment Systems (SDEWES) conferences have been initiated to provide a venue for the researchers from the SEE region, but also for world-wide researchers and specialists and those interested in learning about the sustainability of development, to present research progress and to discuss the state of the art, the future directions and priorities in the various areas of sustainable development and regional integration.

The 5th SDEWES SEE Conference will be held in Vlorë, Albania, and will continue to successfully cover the following areas (examples in parentheses, but not confined to them), with particular focus on SEE region wherever possible:

- Sustainability comparisons and measurements (metrics and indices; multi-criteria analysis; external costs; exergy analysis; footprint methods; emergy; life cycle analysis)
- Green economy and better governance (circular economy; low carbon development/economy; resource efficiency; water reuse; jobs and regional development; macroeconomic analysis; financial and regulatory mechanisms; models and tools; rebound effect; energy economics; environmental economics; development economics; sustainability economics)
- Smart energy systems (markets; demand response; integration of power, heating/cooling, transport, water and waste sectors; smart grids; dynamic electricity pricing, microgrids)
- Energy policy (security of supply; climate change mitigation; energy transition; renewable energy support schemes; energy efficiency policy; employment creation; carbon pricing; markets; fossil fuel subsidies)
- Smart transport systems and policy (fuel/carbon economy; transport electrification; congestion and road pricing; multimodal management; alternative fuels; social aspects; autonomous mobility; railways; shipping; aviation)
- Water-energy nexus (water management; water system analysis; water pricing; water desalination; hydro energy; water-renewables integration, water resources; river basin management; arid areas)

"You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete."

Buckminster Fuller, philosopher, futurist and global thinker (1895 - 1983)

- Environmental policy and management (waste management; wastewater management; climate change mitigation; climate change adaptation; air pollution policy; water pollution policy; land management; biomass management; rewilding; social aspects; strategic environmental impact assessment, environment and corporate social responsibility, quality management systems; environment management systems; eco management and audit schemes; occupational health and safety assessment systems; hazard analysis and critical control point; integrated management systems)
- Agricultural policy (energy and water use in agriculture and food processing; food vs. biofuels; sustainability of biofuels production)
- Social acceptance (reform; NIMBY; nuclear; wind; biofuels; hydrogen; hidden and special interests; cost based pricing; inclusion; fossil fuel subsidy; green economy and employment; gender issues; energy poverty; energy affordability)
- Sustainable resilience of systems (resilience of energy systems; resilience of water systems; resilience of environmental systems; resilience of agricultural systems; resilience of social systems; resilience of engineering systems)
- Sustainable tourism (green hotels; certification)
- Urbanism (smart cities; urban planning; zoning; transport; zero energy buildings/districts; sustainable energy action plans; district heating/cooling)
- Regional planning and cooperation (sustainable islands; regions and cities; 100% renewable regions)
- Research, innovation and development (industry-academia partnership; quadruple helix; knowledge based society; knowledge management; learning curve; technology foresight; science diplomacy)
- Education in sustainable development (governance; environmental awareness; higher education; engineering education)
- Energy system analysis (energy planning; power system planning; smart energy systems; smart energy networks; natural gas system planning; 100% renewable energy systems; high penetration of renewables; island energy systems; development of energy planning tools; internalizing environmental externalities; electrification of transport; storage vs. grids vs. demand management; long term demand planning; integration of power and district heating systems; integration of power and water systems; integration of power and transport systems; power to gas)
- Transport management (transport system analysis, dynamic road pricing; electrification of transport)
- Renewable energy resources (biomass; hydro; wind; solar; geothermal; wave and ocean; technical and economic potentials; barriers; cost and benefits; integration)
- Primary energy resources (oil peaking; gas; coal peaking; nuclear fuels)
- Renewable electricity generation systems (biomass; hydro; wind; offshore wind; high altitude wind; photovoltaic; concentrated solar thermal power; geothermal; wave; tide; ocean thermal)
- Thermal power plants (clean coal; combined cycles; advanced cycles; flexible operation and cycling; carbon capture and storage/sequestration/reuse; nuclear)
- District heating and/or cooling in smart energy systems (integration of renewable heat; cogeneration; industrial waste/excess heat; waste to energy and CHP; power to heat; electric boilers; heat pumps; integration of CHP with district heating and electricity markets; heat maps; distribution)

- Nano and micro technologies and science for sustainable development of energy, water, and environment systems
- Advanced sustainable energy conversion systems (fuel cells; thermoelectric; thermionic; organic; ORC; waste/excess heat recycling; thermoacoustic; piezoelectric)
- Renewable heat systems (biomass; biofuels; biogas; solar; geothermal)
- Biofuels and biorefineries (biodiesel; bioethanol; biogas; second and third generation biofuels; waste to biofuels; algae; anaerobic digestion; BTL; biorefineries; alternative fuel vehicles; infrastructure; sustainability assessment; pyrolysis; torrefaction; coproduction)

"If there are to be problems, may they come during my life-time so that I can resolve them and give my children the chance of a good life."

Kenyan proverb

- Alternative fuels (hydrogen; electro-fuels; power to gas; synthetic fuels; BTL; DME; CNG; resources; production; vehicles; infrastructure)
- Hybrid and electric vehicles (first generation hybrid; plug in hybrid; charging; batteries; infrastructure)
- Water treatment for drinking water
- Water desalination (distillation; reverse and forward osmosis; electrodialysis; energy recovery; discharge management)
- Waste and wastewater treatment and reuse (avoiding waste; composting; recycling; waste to energy; anaerobic digestion; gasification; mechanical biological treatment; mechanical heat treatment; plasma arc waste disposal; pyrolysis; RDF/SRF; combustion modelling)
- Modelling for pollution avoidance and energy efficiency (CFD models; air pollution spreading; water pollution spreading; heat and mass transfer modelling combustion modelling)
- Cogeneration, trigeneration, polygeneration (heat/cold and power; water and power; biofuels and power; transport and energy; food and energy; applications and operation strategies)
- Storage (heat/cold storage; hydrogen storage; hydropower as storage; pump storage; compressed air storage; batteries; water storage; biofuels storage; storage optimisation modelling; financial support mechanisms; power market arbitrage)
- Electricity transmission and distribution (grid extension and robustness; long distance transmission; power quality)
- Gas security of supply (diversification; shale gas; extension of transmission pipelines; LNG; Southern Corridor)
- Energy and water efficiency in industry and mining (cement and lime; construction materials; glass; pulp and paper; food industry; metallurgy; chemical industry; process optimisation; kilns; boilers; heat exchange networks; pinch analysis; exergy and exergoeconomic analysis; energy audits; water use and waste minimisation; eco-innovation; total site integration; life cycle assessment; eco-design and eco-labelling; product cycle assessment; cleaner production, environmental impact assessment)
- Energy efficient appliances (smart appliances; labelling and standards; user behaviour)
- Buildings (nearly zero energy buildings; passive buildings; smart buildings; smart metering; ICT; load and demand side management; green buildings; building codes and standards; buildings certification; HVAC; insulation; renewables integration; heat pumps; storage; sustainable architecture)

- Energy markets (market/price coupling; liberalisation/deregulation; modelling; demand response; role of district heating; desalination and water pumping; storage; retail markets; grid parity; net metering)
- Emission markets (emission trading system; cap and trade; transport participation)
- Political aspects of sustainable development (long term planning; sustainable development goals; the role of political leaders and of voters; international conflict vs. sustainable development; security and sustainability; resource and political security)

"Then I say the Earth belongs to each generation during its course, fully and in its right no generation can contract debts greater than may be paid during the course of its existence"

Thomas Jefferson, September 6, 1789

In addition, acknowledging that regional coordination is the only feasible solution for gaining synergy effects for the small and only partially connected emerging energy markets of the Southeastern Europe, the Conference will address the core goals of the Energy Community and the wider region:

- Competitive integrated regional energy market (regional cooperation, market opening, price reform, regulatory framework and independence, coordination on regional projects, market coupling)
- Security of supply (diversification of fuels, energy efficiency, oil and gas storages, regional emergency response, energy and water scarcity)
- Climate change and environment (regional emissions reduction plans, fuel mix in power generation - renewable energy - gasification - energy efficiency, intelligent use of energy)
- Infrastructure development (Mediterranean power ring, Southern Corridor, investment projects of regional interest - minimum definition criteria, investments in the gas sector, electricity interconnections, grid access and integration of renewable energy)
- Social dimension (energy poverty, definition of vulnerable customers, protection schemes, stepwise phasing out of regulated energy prices, fossil fuel subsidies)
- External relations in light of sustainable development (enlargement - EU neighbours, cooperation with other international organizations)

Preface

The objective of the series of conferences on Sustainable Development of Energy, Water and Environment Systems (SDEWES) is to provide a forum for world-wide specialists and those interested in learning about the sustainability of development, to present research progress and to discuss the state of the art, the future directions and priorities in the various areas of sustainable development. This includes the improvement and dissemination of knowledge on methods, policies and technologies for increasing the sustainability of development, taking into account its economic, environmental and social pillars, as well as methods for assessing and measuring sustainability of development, regarding climate, energy, transport, agriculture, water and environment systems and their many combinations. The reason for the forum having such a wide scope is due to the need for holistic integrated solutions encompassing several or all.

Prof. Maria da Graça Carvalho

Chair of the International Scientific Committee

Prof. Ivo Šlaus

Chair of the Scientific Advisory Board

Prof. Kledi Xhaxhiu

Chair of the Local Organising Committee

Prof. Neven Duić

SDEWES Centre President

Prof. Zvonimir Guzović

Conference Secretary

BOOK OF ABSTRACTS

Contents

SEE2022.0096

Grid Operation and Investment Limitations for Variable Renewable Energy in Integrated Assessment Modelling

I. Batas Bjelic*[1], N. Rajaković[2], I. Capellan-Perez[3], G. Parrado-Hernando[4], L. Herc[5], A. Pfeifer[6], N. Duić[7]

[1]Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, Serbia; [2]University of Belgrade, School of Electrical Engineering, Serbia; [3]University of Valladolid, Spain; [4]University of Valladolid, School of Industrial Engineering, Spain; [5]Faculty of Mechanical Engineering and Naval Architecture, Croatia; [6]University of Zagreb - Faculty of Mechanical Engineering and Naval Architecture, Croatia; [7]University of Zagreb, Croatia (*ilija.batas@gmail.com)

Abstract

In order to integrate more and more variable renewable energy sources (VRES) electric grids play a significant role. There is an obvious need for more interconnections and more enhanced grids with more VRES. On the other side, the monetary, material, social and spatial constraints (free corridors) impose limits on grid expansions. Robust modelling of electric grids (distribution, transmission and interconnection) at World level in integrated assessment models (IAMs) is beyond the state of the art of current computation capabilities and data availability. A number of relevant input data like length of the grids, voltage levels, rated power, and after that material prices, population density, VRES shares of generation and flexibility technologies, hourly curtailments in the energy system are not sufficient to calculate explicit limitations imposed by power flows. Therefore, the idea of this paper is that in the absence of sufficient data and computability, for the first time some expert assumptions in the form of proportions are used to represent interconnection grids as an important constraint and flexibility option for variable renewable energy production, modelled at hourly level during one year using EnergyPLAN. These assumptions are about proportions of newly integrated renewable energy between transmission and distribution grids, proportions of grids to the generation plants and their utilization. Suggested method for application in WILIAM will be illustrated.