

# 16<sup>th</sup> IIR-Gustav Lorentzen Conference on Natural Refrigerants



**August 11–14, 2024**

University of Maryland • College Park, Maryland, USA

**Natural Refrigerants for the Present and the Future**



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# 16<sup>th</sup> IIR-Gustav Lorentzen Conference on Natural Refrigerants



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# Scientific Committee and Organizing Committee



## Scientific Committee

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Jae Dong Chung (South Korea)  
Lorenzo Cremaschi (USA)  
Marian Formanek (CzechRepublic)  
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Bartosz Zajackowski (Poland)  
Hua Zhang (China)

## IIR Director General

Yosr Allouche  
Associate Professor in  
Refrigeration  
NTNU, Norway

## Organizing Committee

Dr. Yunho Hwang  
Co-Director,  
Center for Environmental Energy Engineering  
University of Maryland

Dr. Vikrant Aute  
Co-Director  
Center for Environmental Energy Engineering  
University of Maryland

Dr. Reinhard Radermacher  
Director  
Center for Environmental Energy Engineering  
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Leanne Poteet, Program Secretariat  
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# Welcome



Dear Colleagues and Attendees,

As our planet grapples with the escalating climate crisis—marked by rising temperatures and increasing demands for cooling solutions and decarbonizing heating solutions—the need for innovative and sustainable technologies has never been more urgent. The 16th Gustav Lorentzen Conference on Natural Refrigerants serves as a vital platform for confronting this global challenge.

Hosted by the Center for Environmental Energy Engineering (CEEE) at the University of Maryland, this conference reflects our commitment to pioneering sustainable cooling technologies. The CEEE's dedicated researchers are at the forefront of developing environmentally friendly alternatives to conventional refrigerants and heating and cooling systems. We are honored to host this prestigious event and to advance the dialogue on these critical issues.

This year's conference theme, "Natural Refrigerants for the Present and the Future," addresses a pressing question: How can we meet the increasing demand for cooling and heating systems while mitigating our impact on the climate?

With over 200 research abstracts submitted, we are thrilled to present 140 innovative papers that explore advancements in natural refrigerants, covering topics such as heat transfer, components, systems, safety, controls, and life cycle analysis. We extend our heartfelt gratitude to the authors for their exceptional contributions, as well as to the session chairs and volunteers whose efforts have made this program possible.

Thank you for your participation and engagement in this crucial discussion.

Sincerely,

The Organizing Committee

**Yunho Hwang**, Co-Director, Center for Environmental Energy Engineering

**Vikrant Aute**, Co-Director, Center for Environmental Energy Engineering

**Reinhard Radermacher**, Director & Co-Founder, Center for Environmental Energy Engineering



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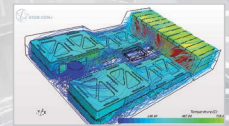
Electric Compressor R744, R290



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# Plenary Speakers | Monday



## **Björn Palm**

**Monday | 8:30 am**

### **Hydrocarbon Heat Pumps - a European Perspective**

Björn Palm, Ph.D., is senior professor in energy technology at KTH, Royal Institute of Technology, in Stockholm, Sweden, where he headed the Division of Applied Thermodynamics and Refrigeration for over 20 years. His research covers components and systems for heat pumps and refrigeration systems, from microstructures of boiling surfaces, to combinations of heat pumps and thermal energy storage for load shifting in the energy system. A special interest has been the application of natural refrigerants like hydrocarbons and carbon dioxide, and the use of ammonia in small systems.

Dr. Palm will speak about "Hydrocarbon Heat Pumps - a European Perspective." The phaseout of fossil fuels is necessary to reach the Paris Agreement goals and to limit global warming to acceptable levels. An important consequence is the electrification of the heating sector, which will force a rapid increase in the use of heat pumps. This presentation will discuss the background and the development of the heat pump market from a European perspective. New restrictions on F-gases, possible bans of all PFAS-substances and the response from the heat pump market in Europe will also be covered.



## **Eric M. Smith**

**Monday | 9:15 am**

### **IIAR's Role in the Safe and Efficient Use of Natural Refrigerants**

Eric M. Smith, P.E., is Vice President and Technical Director of The International Institute of All-Natural Refrigeration (IIAR). His main responsibilities include management of standards and guidelines development, consultation and assistance to IIAR committees, initiation and coordination of research projects, regulatory outreach, and advocacy.

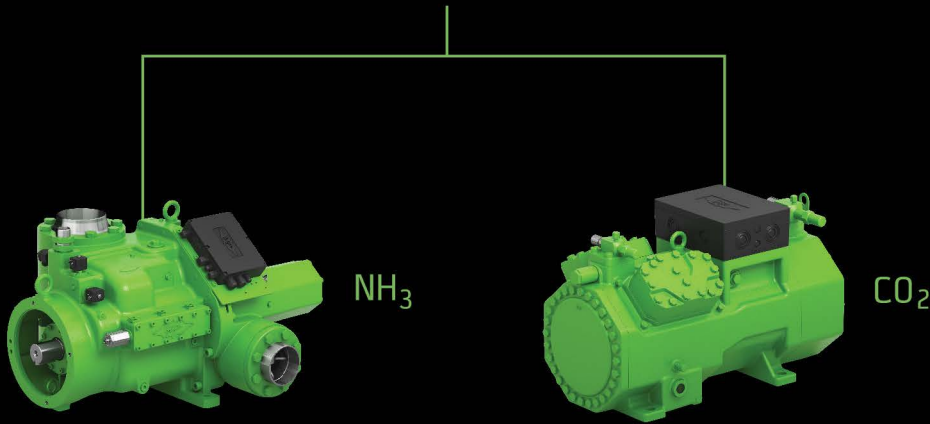
His presentation will provide an "Overview of IIAR's Role in the Safe and Efficient Use of Natural Refrigerants." IIAR is a nonprofit professional society and trade association dedicated to the safe use of natural refrigerants such as ammonia, carbon dioxide and propane. IIAR develops and maintains ANSI standards that are directly referenced by building codes and are recognized and generally accepted as good engineering practices by the industry and regulatory agencies. IIAR offers many other guidelines and educational opportunities related to safety, efficiency and other best practices in the use of natural refrigerants.



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[www.iiar.org](http://www.iiar.org)

## Plenary Speakers | Tuesday



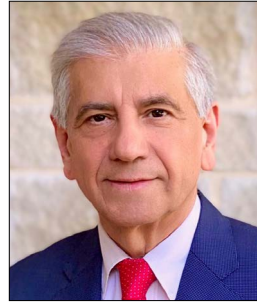
### **Hannes Fugmann**

**Tuesday | 8:30 am**

#### **R290 Heat Pump Developments in Europe - Technologies and Safety Measures**

Hannes Fugmann, Ph.D., heads the Vapor Compression Technology group at the Fraunhofer Institute for Solar Energy Systems in Freiburg, Germany. His research primarily centers on developing compact and efficient heat exchangers for heating and air conditioning applications. Additionally, Dr. Fugmann is dedicated to innovating charge-reduced refrigerant circuits for heat pumps, with a particular emphasis on using propane as a refrigerant. He also is deeply involved in ensuring the safety of heat pump systems, addressing the risks associated with natural, but flammable refrigerants.

Dr. Fugmann will speak about "R290 Heat Pump Developments in Europe - Technologies and Safety Measures." Heat pumps using R290 (propane) are increasingly being installed in the residential sector in Europe. The development of R290 heat pumps is linked to European regulations, such as the regulation on fluorinated greenhouse gasses, and on national funding for installation. R290 is efficient and climate-friendly, but manufacturers must address the flammability. Dr. Fugmann will share some of the safety concepts used in Europe and discuss methods for evaluation.



### **Zahid Ayub**

**Tuesday | 9:15 am**

#### **Prospects of Aggressive Use of Natural Refrigerants**

Zahid Ayub, Ph.D., P.E., is president of Isotherm, Inc., a manufacturer of heat transfer equipment and systems. Dr. Ayub has designed and fabricated several thousand heat exchangers/pressure vessels and systems installed worldwide. He is recognized as one of the pioneers in the field of Ammonia Enhanced Heat Transfer.

Dr. Ayub will speak about the "Prospects of Aggressive Use of Natural Refrigerants." He'll discuss how time-tested natural refrigerants can fill in for synthetic refrigerants. Ammonia's track history spans over 100 years. The use of carbon dioxide as a refrigerant is on the rise. Both of these natural refrigerants have their pros and cons. The idea is to manage the cons and develop components that would result in compact and efficient systems. This presentation offers a bird's eye view on the topic, covering current developments and the future outlook.



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# Program at a Glance



## SUNDAY, AUGUST 11

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4:00 PM Registration | 4:00-7:00 PM

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6:00 PM Welcome Reception | 6:00-8:00 PM

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## MONDAY, AUGUST 12

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7:00 AM Registration | 7:00 AM-4:00 PM

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7:30 AM Breakfast

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8:00 AM Opening Ceremony

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8:30 AM Plenary Speaker Björn Palm, KTH

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9:15 AM Plenary Speaker Eric M. Smith, IAR

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10:30 AM **A1: Refrigerants 1: CO2/HC**  
**B1: Components-Heat Exchanger 1**  
**C1: Components-Compressor 1**  
**D1: Heat Transfer**

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12:00 N Lunch

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1:00 PM **A2: Systems 1: CO2**  
**B2: Components-Ejector**  
**C2: Modeling 1**  
**D2: Modeling 2**

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3:00 PM IIR Commission B1/B2 Meeting

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4:00 PM Excursions to Washington, DC

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## TUESDAY, AUGUST 13

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7:00 AM Registration | 7:00 AM-10:00 AM

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7:30 AM Breakfast

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8:30 AM Plenary Speaker Hannes Fugmann,  
Fraunhofer Institute for Solar Energy  
Systems

---

9:15 AM Plenary Speaker Zahid Ayub, Isotherm

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10:30 AM **A3: Refrigerants 2: HCs**  
**B3: Components-Heat Exchanger 2**  
**C3: Components-Compressor 2**  
**D3: Not-In-Kind 1**

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12:00 N Lunch

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1:00 PM **A4: Systems 2: HCs**  
**B4: Components-Heat Exchanger 3**  
**C4: Modeling 3**  
**D4: Refrigerant Safety**

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3:30 PM **A5: Systems 3: Natural Refrigerants**  
**B5: Systems 4: HTHP 1**  
**C5: Workshop: Decarbonization Through Adopting  
Low-GWP Refrigerants**  
**D5: Thermal Management & CFD Analysis**

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6:00 PM Conference Banquet | 6:00-9:00 PM

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## WEDNESDAY, AUGUST 14

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7:30 AM Breakfast

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8:00 AM **A6: Systems 5: District Heating**  
**B6: Systems 6: HTHP 2**  
**C6: Field Testing**  
**D6: Market Analysis**

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10:30 AM **A7: Systems 7: Transport**  
**B7: Measuring Methods**  
**C7: Operations & Controls**  
**D7: Not-In-Kind 2**

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12:00 N Lunch & Closing Ceremony

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1:00 PM Lab Tours | 1:00-2:30 PM

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To access the  
mobile app for the  
Gustav Lorentzen  
Conference, please  
use this QR code:



# Conference Schedule



## Sunday

4:00 pm-7:00 pm **Conference Registration** | First Floor Entryway, Edward St. John

6:00 pm-8:00 pm **Welcome Reception** | First Floor Hallway, Edward St. John

## Monday

7:00 am-4:00 pm **Conference Registration** | First Floor Entryway, Edward St. John

7:30 am-8:30 am **Breakfast** | First Floor Hallway, Edward St. John

8:00 am-8:30 am **Conference Opening Ceremony** | Ground Floor, Room 0202, Edward St. John

8:30 am-9:15 am **Plenary Speaker: Björn Palm** | Ground Floor, Room 0202, Edward St. John

9:15 am-10:00 am **Plenary Speaker: Eric M. Smith** | Ground Floor, Room 0202, Edward St. John

10:00 am-10:30 am **Coffee Break** | First Floor Hallway, Edward St. John

ESJ, Room 0202

ESJ, Room 1224

ESJ, Room 1202

ESJ, Room 1215

10:30 am-12:00 noon

**Session A1**  
Refrigerants 1: CO2/HC

**Session B1**  
Components-Heat Exchanger 1

**Session C1**  
Components-Compressor 1

**Session D1**  
Heat Transfer

12:00 noon-1:00 pm **Lunch** | Colony Ballroom, Stamp Union

ESJ, Room 0202

ESJ, Room 1224

ESJ, Room 1202

ESJ, Room 1215

1:00 pm-3:00 pm

**Session A2**  
Systems 1: CO2

**Session B2**  
Components-Ejector

**Session C2**  
Modeling 1

**Session D2**  
Modeling 2

3:00 pm-4:00 pm **Coffee Break** | First Floor Hallway, Edward St. John

3:00 pm-4:00 pm **IIR Commission B1/B2 Meeting** | Room 1309, Edward St. John

4:00 pm-9:00 pm **Excursions to Washington, DC** | Meet buses in Regents Drive Garage, 8056 Regents Drive

# Conference Schedule



## Tuesday

7:00 am-10:00 am	<b>Conference Registration</b>   First Floor Entryway, Edward St. John			
7:30 am-8:30 am	<b>Breakfast</b>   First Floor Hallway, Edward St. John			
8:30 am-9:15 am	<b>Plenary Speaker:</b> Hannes Fugmann   Ground Floor, Room 0202, Edward St. John			
9:15 am-10:00 am	<b>Plenary Speaker:</b> Zahid Ayub   Ground Floor, Room 0202, Edward St. John			
10:00 am-10:30 am	<b>Coffee Break</b>   First Floor Hallway, Edward St. John			
	ESJ, Room 0202	ESJ, Room 1224	ESJ, Room 1202	ESJ, Room 1215
10:30 am-12:00 noon	<b>Session A3</b> Refrigerants 2: HCs	<b>Session B3</b> Components-Heat Exchanger 2	<b>Session C3</b> Components-Compressor 2	<b>Session D3</b> Not-in-Kind 1
12:00 noon-1:00 pm	<b>Lunch</b>   Colony Ballroom, Stamp Union			
	ESJ, Room 0202	ESJ, Room 1224	ESJ, Room 1202	ESJ, Room 1215
1:00 pm-3:00 pm	<b>Session A4</b> Systems 2: HCs	<b>Session B4</b> Components-Heat Exchanger 3	<b>Session C4</b> Modeling 3	<b>Session D4</b> Refrigerant Safety
3:00 pm-4:00 pm	<b>Coffee Break</b>   First Floor Hallway, Edward St. John			
	ESJ, Room 0202	ESJ, Room 1224	ESJ, Room 1202	ESJ, Room 1215
3:30 pm-5:30 pm	<b>Session A5</b> Systems 3: Natural Refrigerants	<b>Session B5</b> Systems 4: HTHP 1	<b>Session C5</b> Workshop: Decarbonization	<b>Session D5</b> Thermal Mgmt & CFD Analysis
6:00 pm-9:00 pm	<b>Conference Banquet</b>   Colony Ballroom, Stamp Union			

## Wednesday

7:30 am-8:30 am	<b>Breakfast</b>   First Floor Hallway, Edward St. John			
	ESJ, Room 0202	ESJ, Room 1224	ESJ, Room 1202	ESJ, Room 1215
8:00 am-10:00 am	<b>Session A6</b> Systems 5: District Heating	<b>Session B6</b> Systems 6: HTHP 2	<b>Session C6</b> Field Testing	<b>Session D6</b> Market Analysis
10:00 am-10:30 am	<b>Coffee Break</b>   First Floor Hallway, Edward St. John			
	ESJ, Room 0202	ESJ, Room 1224	ESJ, Room 1202	ESJ, Room 1215
10:30 am-12:00 noon	<b>Session A7</b> Systems 7: Transport	<b>Session B7</b> Measuring Methods	<b>Session C7</b> Operations & Controls	<b>Session D7</b> Not-in-Kind 2
12:00 noon-1:00 pm	<b>Lunch and Closing Ceremony</b>   Colony Ballroom, Stamp Union			
1:00 pm-2:30 pm	<b>Lab Tours</b>   Meet in Colony Ballroom			

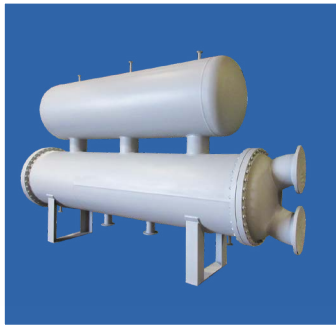
# INDUSTRIAL REFRIGERATION



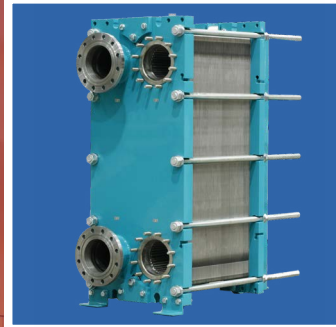
**Low Charge  
SX Evaporator**



**Low Charge  
Vertical Evaporator**



**Shell and Tube  
Heat Exchanger**



**Plate and Frame  
Heat Exchanger**



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# Tours of UMD Engineering Labs



**Wednesday August 14 | 1:00-2:30 pm**  
**Meet at Colony Ballroom, Stamp Union**

*Get an insider's look at how University of Maryland researchers are developing the next generation of eco-friendly heating, ventilation, air conditioning and refrigeration (HVAC&R) technologies to help slow climate change. See where our researchers are creating advanced heat transfer technologies, solid-state refrigerants with zero global warming potential and more. You'll also visit the fire protection laboratories used to test flammable refrigerants.*



## **Daikin Energy Innovation Laboratory**

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The Daikin Energy Innovation Laboratory is a 3,600 square foot state-of-the-art facility that features the latest equipment for energy engineering, including flame resistant climate chambers, heat transfer measurement technologies and facilities for experimental alternative cooling technologies. See where our researchers are developing elastocaloric cooling devices that offer a solid-state alternative to vapor-compression technology by using shape memory alloys as refrigerants. The lab is run by the university's Center for Environmental Energy Engineering (CEEE).

## **George E. Dieter, Jr. Materials Instructional Lab**

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At the Dieter Lab, tour attendees will learn more about the University of Maryland's research on elastocaloric cooling, a revolutionary technology that has been shown to offer efficient cooling, with zero direct global warming potential. At the Dieter lab, researchers test the materials and components of the elastocaloric prototype devices developed in the Daikin Energy Innovation Laboratory. In addition to sample preparation (for microscopy, calorimetry, etc.), our engineers conduct a range of mechanical tests such as tension, compression, bending, torsion, fatigue, hardness and impact, using specialized instrumentation. The work is a collaboration between CEEE and the Department of Materials Science and Engineering.

## **Small and Smart Thermal Systems Laboratory**

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The Small and Smart Thermal Systems (S2TS) Laboratory focuses on pioneering applications in energy conversion, heat/mass exchangers, process intensification, electronics cooling, and innovative component design and manufacturing for energy systems. The research encompasses state-of-the-art manufacturing techniques, including additive manufacturing and the application of micro and nano-systems for process intensification and optimization. S2TS is at the forefront of decarbonization efforts, conducting energy audits, energy profiling and energy modeling. The lab is dedicated to developing advanced energy auditing software with machine learning capabilities for precise and efficient energy and carbon assessments and compliance projections. S2TS is home to CEEE's Advanced Heat Exchangers and Process Intensification industrial consortium, and is affiliated with the Center for Advanced Life Cycle Engineering.

## **Fire Protection Engineering Laboratories**

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The University of Maryland offers one of only three graduate fire protection engineering programs in the United States. The department's laboratories support a broad range of experimental research and teaching, including research related to the safety of alternative natural refrigerants, many of which are flammable or mildly flammable. The large burn room allows flammable refrigerant fires of up to 1 MW. Refrigerant flammability and ignitability are tested in our ASTM E 681 facility and in our windowed vessels of up to 125 L.

# Technical Sessions



## MONDAY, AUGUST 12

10:30 AM - 12:00 NOON

### A1: Refrigerants 1: CO<sub>2</sub>/HC | ESJ 0202

Session Chair: Chun-cheng Piao

#### 1106 Experimental Comparison of CO<sub>2</sub> and Different CO<sub>2</sub>/R290 and CO<sub>2</sub>/R1270 Blends in a Transcritical Refrigeration Plant With Different Cycle Arrangements

Rafael Larrondo Sancho\*, Francisco Vidan Falomir, Daniel Sánchez García-Vacas, Ramón Cabello López  
*Jaume I University. Mechanical Engineering and Construction Department. Thermal Engineering Research Group. Castellón (Spain)*

#### 1107 Comparison of CO<sub>2</sub> and Alternative CO<sub>2</sub>/R1270 Mixtures in a Transcritical Refrigerating Plant: Energy Evaluation in an MT Application

Francisco Vidan Falomir\*, Rafael Larrondo Sancho, Daniel Sánchez García-Vacas, Ramón Cabello López  
*Jaume I University. Mechanical Engineering and Construction Department. Thermal Engineering Research Group. Castellón (Spain)*

#### 1108 Experimental Analysis of R744/R290 Blends in a Two-Stage Vapour Compression Heat Pump

Daniel Sánchez García-Vacas\*, Rafael Larrondo Sancho, Ramón Cabello López  
*Jaume I University. Mechanical Engineering and Construction Department. Thermal Engineering Research Group. Castellón (Spain)*

#### 1197 Evaluating the Use of CO<sub>2</sub>-Hydrocarbon Blends as Working Fluids in High Temperature Heat Pumps

Gabriele Toffoletti\*, Emanuele Sicco, Giovanni Cortella, Paola D'Agaro  
*University of Udine, Italy*

### B1: Components-Heat Exchanger 1 | ESJ 1224

Chair: Akio Miyara

#### 1178 Enhancing Heat Transfer Efficiency of a Gas Cooler in CO<sub>2</sub> Transcritical System Through Evaporative Cooling on Superhydrophilic Fin Surface

Chayan Das (1), Prosenjit Singha (1), Mani Sankar Dasgupta (1)\*, Armin Hafner (2)  
*1: Birla Institute of Technology and Science, India; 2: Norwegian University of Science and Technology, Norway*

#### 1201 Use of Adiabatic Technology for an Efficient Heat Rejection Process in Fin-And-Tube CO<sub>2</sub> Gas Coolers

Stefano Filippini, Giovanni Mariani, Rodolfo Cavicchioli, Dario Demurtas\*  
*LU-VE Group, Italy*

#### 1288 Refrigerant Charge Calculation Method for Brazed Plate Evaporators and Condensers

Torsten Will\* (1) (2), Lena Schnabel (1), Jürgen Köhler (2)  
*1: Fraunhofer-Institut for Solar Energy Systems ISE, Germany; 2: Technical University Braunschweig, Germany*

#### 1149 Pressure Drops in Small-Diameter Tube U-Bends for Heat Exchangers Used for Low-Temperature Ammonia Refrigeration Applications

Jerin Robin Ebanesar (1), Ahmad Abbas (1,2), Christian Fauer (1), Lorenzo Cremaschi\* (1), Zahid Ayub (3)  
*1: Auburn University, USA; 2: GIK Institute of Engineering Sciences and Technology, Pakistan; 3: Isotherm, Inc., USA*

\* indicates the presenter

# Technical Sessions



## C1: Components-Compressor 1 | ESJ 1202

Chair: Baolong Wang

### 1184 Optimal Design of Two-Stage Cylinder Diameters for Enhanced Performance in a Dual-Piston Carbon Dioxide Linear Compressor

Mingsheng Tang (1,3), Fanchen Kong\* (1, 2, 3), Huiming Zou (1,3), Shuo Zhang (1, 2, 3), Zhouhang Hu (1, 2, 3), Changqing Tian (1, 3)  
1: Technical Institute of Physics and Chemistry, Chinese Academy of Sciences: Beijing, China; 2: University of Chinese Academy of Sciences: Beijing, China; 3: Key Laboratory of Cryogenic Science and Technology: Beijing, China

### 1196 Numerical Modelling of the Solid- and Fluid Dynamic Phenomena Controlling the Ring Plate Valve Motion and Tumbling

Åsmund Ervik\* (1), Afaf Saai (2), Torodd Berstad (3), Ole Meyer (1), Takuma Tsuji (4), Tatsuya Oku (4), Kazuhiro Hattori (4), Petter Nekså (1)  
1: SINTEF Energy Research, 7034 Trondheim, Norway; 2: SINTEF Industry, Trondheim, Norway; 3: Norwegian University of Science and Technology, Trondheim, Norway; 4: Mayekawa MFG Co. LTD., Botan Koto ku, Tokyo, Japan

### 1102 Variable-Speed Compressor Ratings Displayed Within Single Third-Degree Polynomial Function

Tobias Guth (1), Gerhard Frei (2), Mihaela Frei (2), Sylvia Schädlich (1)  
1: Ruhr West University of Applied Sciences, Institute of Energy Systems and Energy Management Bottrop, Germany; 2: COOLPLAN, Engineering Office for Refrigeration, Munich, Germany

## D1: Heat Transfer | ESJ 1215

Chair: Giovanni Longo

### 1101 CO2 Flow Boiling Heat Transfer Evaluation and Visualization in a Horizontal Round Tube with and without Oil at Low Temperatures

Hui Zhao (1,2), Xiaochuan Li (1), Ke Tang (1,2), Kazuhiro Hattori (3), Nelson Mugabi (3), Stefan Elbel\* (1,4)  
1: Creative Thermal Solutions, Inc., USA; 2: University of Illinois at Urbana-Champaign, USA; 3: Mayekawa Mfg. Co., Ltd., Japan; 4: Technische Universität Berlin, Germany

### 1244 Towards Defining the Optimal Design Parameters for a Test Setup Studying Heat Transfer With Carbon Dioxide at Supercritical Conditions

Camila Pedano\* (1), Paolo Petagna (1), Susanne Mall-Gleissle (2)  
1: CERN, Switzerland; 2: Offenburg University of Applied Sciences, Germany

### 1110 Theoretical and Experimental Assessment of Propane and Propylene as Substitutes for Traditional HFC Refrigerants R410A and R404A

Giovanni A. Longo\*  
University of Padova, Italy

### 1138 The Effect of Lubricant Oil on Evaporation Heat Transfer for Ammonia Falling Liquid-Film

Ikuro Akada\* (1), Kosaku Nishida (1), Norihiro Inoue (2)  
1: Mayekawa Mfg. Co., Ltd.; 2: Tokyo University of Marine Science and Technology

# Technical Sessions



## MONDAY, AUGUST 12

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1:00 PM - 3:00 PM

### A2: Systems 1: C02 | ESJ 0202

Chair: Armin Hafner

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#### 1209 The Combined Potential of Using Air and Solar Source Evaporators in a CO2 Heat Pump

Riccardo Conte (1), Emanuele Zanetti (2), Marco Tancon (1), Sergio Girotto (3), Marco Azzolin\* (1), Davide Del Col (1)

1: Dept of Industrial Engineering, University of Padova, Italy; 2: Department of Process and Energy, Delft University of Technology, Netherlands; 3: ENEX S.r.l., Italy

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#### 1194 First Experimental Results of a R744 Water-to-Water Heat Pump for Space Heating

Chiara D'Ignazi\*, Luca Molinaroli

Politecnico di Milano, Italy

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#### 1126 Development of CO2 Dry Ice Heat Pump System

Hiroshi Yamaguchi\* (1), Takeshi Kamimura (2), Kazuhiro Hattori (2), Petter Neksa (3), and Haruhiko Yamasaki (4)

1: Department of Mechanical Engineering, Doshisha University, 2: Mayekawa Mfg. Co., Ltd, Botan, Koto-ku, Tokyo, Japan, 3: SINTEF Energy Research, Sem Sælands vei 11, Trondheim, Norway, 4: Department of Mechanical Engineering, Osaka Metropolitan University

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#### 1198 Design and Freezing Performance Study of a CO2 Plate Freezer at -50°C Evaporation Temperature

Shuai Ren\* (1), Armin Hafner (1), Inge Håvard Rekstad (1), Kristina Norne Widell (2), Eirik Starheim Svendsen (2), Tom Ståle Nordtvedt (2)

1: NTNU, Norway; 2: SINTEF Ocean, Norway

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#### 1293 Enhancing Cooling Performance of R744 Heat Pump System in Electric Vehicles Using Gas Injection Technology

Seungyeon Lee, Min Soo Kim\*

Seoul National University, Korea, Republic of (South Korea)

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#### 1238 CO2 Heat Pump With and Without Cooling Output for Hot Water Production in Tropical Climates

Y. Siva Kumar Reddy (1), A.M. Guruchethan (1), Sarun Kumar Kochunni (2), Simarpreet Singh (2), Armin Hafner (1), M.P. Maiya (2)\*

Organization(s): 1: Indian Institute of Technology Madras, Chennai, India; 2: Norwegian University of Science and Technology, Trondheim, Norway

### B2: Components-Ejector | ESJ 1224

Chair: Stefan Elbel

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#### 1165 Conceptual Investigation On The Ejector Benefits In R744 Air Conditioning Heat Pump Systems For Electric Vehicles

Reza Niroomand\* (1), Nina Piesch (1), Armin Hafner (1), Krzysztof Banasiak (1), Fadil Ayad (2)

1: Norwegian University of Science and Technology; 2: Thermal Design Solutions Sarl

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#### 1173 Thermodynamic Modelling of Two-Phase R-744 Ejectors in R-744 Heat Pumps

Ekaterini E. Kriezis (1), Baris B. Kanbur (2), Wiebke B. Markussen\* (3)

1: Danfoss A/S, Denmark; 2: Independent Researcher, The Netherlands; 3: Danish Technological Institute

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#### 1148 Theoretical Analysis of the Optimal Ejector Operation Within the Classical Ejector Refrigeration System

Antoine Metsue\* (1,2), Hakim Nesreddine (3), Sébastien Poncet (1), Yann Bartosiewicz (2)

1: Université de Sherbrooke, Canada; 2: UCLouvain, Belgium; 3: Hydro-Québec, Canada

# Technical Sessions



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## 1147 Experimental Investigation of an Ultrahigh-Lift Ejector Cycle With an Additional Subcooling Heat Exchanger

Dominik Herden\* (1), Yixia Xu (1), Riley B. Barta (2), Christiane Thomas (1)

1: TU Dresden Schaufler Chair of Refrigeration, Cryogenics and Compressor Technology; 2: Purdue University School of Mechanical Engineering

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## 1160 Thermodynamical Analysis of Two-Phase Water Steam Ejector In High-Temperature Heat Pumps Cycles

Omar Abu Khass\*, Steffen Klöppel, A. Phong Tran, Panagiotis Stathopoulos, Eberhard Nicke

German Aerospace Center (DLR), Institute of Low-Carbon Industrial Processes Cottbus/Zittau, Germany

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## 1177 R744 Heat Pumps with Ejectors for Heating and/or Cooling: Opportunities, Challenges, and Results

Alessandro Silva\* (1), Oliver Javerschek (2), Florian Simon (2)

1: Bitzer US, Inc., Flowery Branch, USA; 2: Bitzer Kuehlmaschinenbau GmbH, Rottenburg-Ergenzingen, Germany

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## C2: Modeling 1 | ESJ 1202

Chair: Vikrant Aute

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## 1187 Modelling of an Onboard R290 Refrigerated Sea Water System for Ice Production on Small Fishing Vessels in India

Lukas Köster\* (1), Prosenjit Singha (2), Chayan Das (2), Jan Bengsch (1), Armin Hafner (3), Mani Sankar Dasgupta (2), Sarun Kumar Kochunni (3), Kristina Norne Widell (1)

1: Sintef Ocean AS, Norway; 2: Birla Institute of Technology And Science, Pilani (BITS Pilani), India; 3: Norwegian University of Science and Technology

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## 1215 Transient and Dynamic Analysis of Refrigeration System Using Fixed Metering Devices for Natural Refrigerant

Zhequan Jin\* (1), Adrien Reveillere (2), Jinwook Lee (1), Mansu Park (1), Saikhee Oh (1)

1: H&A R&D Center, Home Appliance & Air Solution Company, LG Electronics, Republic of Korea; 2: Siemens Digital Industries Software, France

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## 1128 Pressure Optimization of an R600a-R1150 Auto-Cascade Cycle for Ultra-Low Temperature Applications

Manel Martínez Angeles\* (1), Alessia Berton (2), Laura Nebot Andrés (1), Giovanni Cortella (2), Daniel Calleja Anta (1), Rodrigo Llopis (1)

1: University Jaume I, Spain; 2: Università degli Studi di Udine, Italy

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## 1280 CO2 Rack at Low Ambient Temperature: Challenge or Blessing—Part II: Annual Energy Cost Analysis

Daqing Li, Suresh Shivashankar\*, Autumn N. Nicholson, Kurt J. Knapke

Copeland, USA

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## 1168 Shape Optimization and Fluid Control of Near Isothermal Compressor for Transcritical Carbon Dioxide Cycle

Haopeng Liu\*, Vikrant Aute, Yunho Hwang, Chengyi Lee, Jan Muehlbauer, Lei Gao

University of Maryland, USA

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## 1127 A Transcritical R744 Refrigeration System Integrated with Pressure Exchanger for Heat Recovery - A Novel Dynamic Analysis for Supermarket Application

Ayan Sengupta, Mani Sankar Dasgupta\*

Department of Mechanical Engineering, BITS Pilani, India

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# Technical Sessions



## D2: Modeling 2 | ESJ 1215

Chair: Minsoo Kim

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### 1193 Multi-Objective Optimization of a Portable Air Conditioner Operating With R290 Using Genetic Algorithms

William Ferretto\*, Luca Molinaroli  
*Politecnico di Milano, Italy*

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### 1217 Evaluation of the Influence of the Charge Variation in the Performance of an Air-to-Water Heat Pump Working with R290

David Alarcón-Gallén, Belén Llopis-Mengual, Emilio Navarro-Peris\*  
*Universitat Politècnica de Valencia, Spain*

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### 1298 A Refrigerant Charge Prediction Method Based on Pump Down Operation Validated Using Residential and Commercial Heat Pump Systems

Zhenning Li\* (1), Bo Shen (1), Drew Welch (2), Kyle Gluesenkamp (1)  
*1: Oak Ridge National Laboratory, USA; 2: The Helix Innovation Center at Copeland, USA*

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### 1260 Influence of Thermal Energy Storage Integration Strategy on System Performance and Refrigerant Charge for Small-Scale R290 Heat Pumps

Alhussain Othman\*, Vikrant Aute, James Tancabel  
*University of Maryland, USA*

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### 1182 Defrost Modelling and Characteristics of Air Source CO<sub>2</sub> Heat Pumps

Govind Harikumar\* (1), Michele Cattani (1), Jóhannes Kristófersson (2), Pourya Forooghi (1)  
*1: Department of Mechanical and Production Engineering, Aarhus University, Aarhus, Denmark; 2: Danish Technological Institute, Taastrup, Denmark*

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### 1206 Investigating Control Parameters of a CO<sub>2</sub>-Based Thermal Network Connecting Decentralized Heat Pumps

Sepehr Gholamrezaie\*, Massimo Cimmino, Parham Eslami-Nejad  
*Polytechnique Montréal, Canada*

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## TUESDAY, AUGUST 13

10:30 AM - 12:00 NOON

## A3: Refrigerants 2: HCs | ESJ 0202

Chair: Stephen Kujak

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### 1297 Improving R600a Efficiency: RE170/R600 Natural Mixture Analysis

Daniel Calleja-Anta\*, Laura Nebot-Andrés, Manel Martínez-Ángeles, Daniel Sánchez, Rodrigo Llopis  
*Universitat Jaume I, Spain*

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### 1157 Assessment of C<sub>2</sub> to C<sub>5</sub> Aliphatic Hydrocarbons for Future Refrigerant Opportunities

Steve Kujak\*, Michael Petersen  
*Trane Technologies, USA*

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### 1105 Energy Evaluation of Two Hydrocarbons Blends as an Alternative for the HFC R134a in a Vertical Beverage Cooler

Daniel Sánchez García-Vacas\*, Daniel Calleja Anta, Alejandro Andreu Nácher, Ramón Cabello López  
*Jaume I University. Mechanical Engineering and Construction Department. Thermal Engineering Research Group. Castellón (Spain)*

# Technical Sessions



## B3: Components-Heat Exchanger 2 | ESJ 1224

Chair: Lorenzo Cremaschi

### 1263 Optimization of R290 Variable Geometry Heat Exchangers

Brian O'Malley\*, James Tancabel, Vikrant Aute

*Center for Environmental Energy Engineering, Department of Mechanical Engineering, University of Maryland College Park, USA*

### 1269 Development of High-Performance Condenser and Evaporator Heat Exchangers for a High-Temperature Heat Pump Utilizing a Natural Refrigerant

Amir H. Z. Tari\*, Thais P.A. Ferreira, Andres Sarmiento, Michael Ohadi

*Advanced Heat Exchangers and Process Intensification Laboratory, University of Maryland, College Park, Maryland, USA*

### 1241 Design Optimization of Heat Exchangers Utilizing Shape-Optimized, Non-Round Tubes for a Residential Air-Conditioning System Using R290

Vijay Preetham Meruva\*, James Tancabel, Vikrant Aute

*Center for Environmental Energy Engineering, Department of Mechanical Engineering, University of Maryland, College Park, Maryland, USA*

### 1249 CFD-based Correlation Development for sCO<sub>2</sub> in TPMS-Based Heat Exchangers for Heat Pump Water Heater Systems

Arpita Das\*, James Tancabel, Vikrant Aute

*Center for Environmental Energy Engineering, Department of Mechanical Engineering, University of Maryland*

## C3: Components-Compressor 2 | ESJ 1202

Chair: Petter Nekså

### 1183 Study on Dynamic Characteristics of a Self-Lubricating Linear Compressor Using Vapor Injection

Shuo Zhang\* (1,2), Huiming Zou (1), Fanchen Kong (1,2), Mingsheng Tang (1)

*1: Key Laboratory of Cryogenic Science and Technology, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing, China; 2: University of Chinese Academy of Sciences, Beijing, China*

### 1218 Experimental Analysis of the Performance of a Reciprocating Compressor Working with Propane and PAG Oil

Marco Azzolin\* (1), Riccardo Conte (1), Simone Seresin (1), Corrado De Gioia Carabbelese (2), Maurizio Mastrapasqua (2), Davide Del Col (1)

*1: Department of Industrial Engineering, University of Padova, Italy; 2: Frascold SpA, Italy*

### 1292 Oil Sump Temperature in a High-Pressure Shell Scroll Compressor

Nicolás Gómez Parada, Francisco Barceló Ruescas, José González Maciá\*

*Universitat Politècnica de València, Instituto de Ingeniería Energética, Valencia, Spain*

### 1286 Development, Experimental Testing, and Performance Analysis of a Two-Stage Steam Turbo Compressor HTHP for Solar Assisted Heat

Joshua Dowdell\* (1), Ole Marius Moen (1), Magnus Rotan (1), Christian Schlemminger (1,2)

*1: SINTEF Energy Research, Norway; 2: Aneo Industry, Norway*

# Technical Sessions



## D3: Not-In-Kind 1 | ESJ 1215

Chair: Minsung Kim

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### 1306 All-in-One Air Conditioning System for MXene Catalyst-Based H<sub>2</sub>O and CO<sub>2</sub> Adsorption

Joo Young Shin, Do Seong Yoon, Yong Tae Kang\*

*Korea University, Korea, Republic of South Korea*

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### 1302 Study on Membrane-Based Vacuum Dehumidification Technology With Finite Permeance and Selectivity

Donik Ku (1), Soyeon Kim (1), Minkyu Jung (1), Young Soo Chang (2), Minsung Kim\* (1)

*1: Chung-Ang University, Republic of Korea; 2: Kookmin University, Republic of Korea*

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### 1273 Optimal Solution Flow Rate of Liquid Desiccant Air-Conditioning System for Energy Saving

Atsuya Tokano\*, Tsubasa Nishiguchi, Seiichi Yamaguchi

*Waseda University, Japan*

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### 1204 Performance Improvement of Liquid Desiccant Air-Conditioning System With Tube-Extruded Distributor and Surface Treatment of Three-Fluid Contactor

Katsuya Masuno\* (1), Kento Maeda (1), Bowen Cao (2), Moojoong Kim (3), Kiyoshi Saito (1)

*1: Department of Applied Mechanics and Aerospace Engineering, Waseda University; 2: School of Energy and Environment, Southeast University; 3: Research Institute for Science and Engineering, Waseda University*

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## TUESDAY, AUGUST 13

1:00 PM - 3:00 PM

## A4: Systems 2: HCs | ESJ 0202

Chair: Kashif Nawaz

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### 1203 Performance Evaluation of a Low-Charge R290 Modular Heat Pump System

Mathilde Wirtz\*, Jason Woods, Ransisi Huang, Juan Catano, Eric Kozubal

*National Renewable Energy Laboratory, USA*

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### 1236 Experimental Evaluation of a Novel Residential Propane (R290) Two-Stage Heat Pump System

Abd Alrhman Bani Issa\*, Changkuan Liang, HeeJun Shin, Haotian Liu, Eckhard Groll, Davide Ziviani

*Ray W. Herrick Laboratories, School of Mechanical Engineering, Purdue University*

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### 1131 A Saturation Heat Pump System for Cold Climate Conditions

Andrew Fix\*, Lei Gao, Tamoy Seabourne, Jangho Yang, Jan Muehlbauer, Yunho Hwang, Reinhard Radermacher

*Univ of Maryland-Center for Environmental Energy Engineering, USA*

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### 1130 An Energy-Efficient Multi-Drying-Chamber-Based Heat Pump Wood Drying System

Andrew Fix, Yong Pei, Tamoy Seabourne\*, Jangho Yang, Lei Gao, Jan Muehlbauer, Yunho Hwang, Reinhard Radermacher, Bao Yang

*Univ of Maryland-Center for Environmental Energy Engineering, USA*

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### 1192 Performance Analysis of an Active On-Board Refrigeration System Using Propane for Improved Fish Preservation in Small Fishing Boats

Prosenjit Singha (1), Chayan Das (1), Lukas Köster (2), Sarun Kumar Kochunni (4), Mani Sankar Dasgupta\* (1), Kristina Norne Widell (2), Souvik Bhattacharyya (3), Armin Hafner (4)

*1: Birla Institute of Technology and Science, Pilani, India; 2: SINTEF Ocean; 3: TCG CREST; 4: Norwegian University of Science and Technology*



# Technical Sessions



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## 1155 Energy Efficient R-290 based Solar Micro Cold Store: An Experimental Assessment

Harischander Harischander\*, Milind V Rane, Aditya M Rane  
*IIT Bombay, India*

## B4: Components-Heat Exchanger 3 | ESJ 1224

Chair: Rene Rieberer

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## 1214 Heat Recovery Performance of an Integrated CO<sub>2</sub> Commercial Refrigeration System With Dedicated Mechanical Subcooler

Emanuele Sicco\*, Gabriele Toffoletti, Paola D'Agaro, Giovanni Cortella  
*University of Udine, Italy*

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## 1222 Low Charge R290-Subcooler to Improve the Performance of R744-Refrigeration Systems

Gerhard Pertiller\* (1), René Rieberer (1), Leopold Schöffl (2), Alexander Kotenko (2)  
*1: Graz University of Technology, Austria; 2: HAUSER Kühlmöbel und Kältetechnik GmbH, Austria*

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## 1221 Performance Evaluation of a Transcritical CO<sub>2</sub> Refrigeration System for Supermarkets in Hot Climatic Conditions

Shubhanshu Rai\*, Anil Kumar, Anish Modi  
*Department of Energy Science and Engineering, Indian Institute of Technology Bombay, Mumbai, India*

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## 1250 Thermodynamic Optimization and Field Tests of Advanced CO<sub>2</sub> Booster Systems with Integrated Mechanical Subcooling

Rodrigo Llopis\* (1), Javier Atencia (2), Jesús Catalán (2), Takeshi Nishikawa (2), Laura Nebot-Andrés (1)  
*1: Thermal Engineering Group, Jaume I University, Spain; 2: TEWIS Smart Systems S.L.U., Spain*

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## 1248 A Simulation of a Novel Combination of a Compression Heat Pump and a Thermoelectric Heat Pump to Increase the Efficiency

Johannes Brunder\*, Nico Mirl, Konstantinos Stergiaropoulos  
*University of Stuttgart, Germany*

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## 1242 2-Phase CO<sub>2</sub> Pressure Drop Measurements in Vertical and Horizontal Coaxial Transfer Lines for Cooling High-Energy Physics Detectors

Tymon Pakulski\*, Viren Bhanot, Yann Herpin, Bart Verlaet  
*CERN, Switzerland*

## C4: Modeling 3 | ESJ 1202

Chair: Zhenning Li

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## 1186 Model Based Performance Analysis of a Transcritical Combined Heating and Cooling CO<sub>2</sub> Cycle for a School Cantina in India

Marco Bless\* (1), Davide Tommasini (1), Vinod Laguri (2), Krzysztof Banasiak (1), Armin Hafner (3), Pramod Kumar (2)  
*1: SINTEF Energy Research, Norway; 2: Indian Institute of Science, India; 3: Norwegian University of Science and Technology, Norway*

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## 1281 Design of an Integrated Energy System Using a Cascade High Temperature Heat Pump With Zeotropic Refrigerants

Omar Volpato (2), Trygve M. Eikevik\* (1), P. Ganesan (1), Khalid Hamid (1)  
*1: Norwegian University of Science and Technology, Norway; 2: University of Padova, Italy*

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## 1289 Flow-Induced Noise Reduction Using Control Logic in Simultaneous Heating and Cooling Heat Pumps

Changho Han\*, Junhyeok Jang, Yongchan Kim  
*Korea University, Korea, Republic of South Korea*

# Technical Sessions



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## 1109 Heat and Mass Transfer Modelling In a Tubular Bubble Absorber For Absorption Chillers Using Computational Fluid Dynamics

Andres Zapata (1), Carlos Amaris Castilla\* (2)

1: Pennsylvania Department of Environmental Protection, United States; 2: Universidad Industrial de Santander, Colombia

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## 1180 Development of a Residential Thermodynamic Active Mechanical Ventilation Machine Working With Propane

Mirko Buti, Simone Piovesan\*, Paolo Rossi, Yuri Natalini, Andrea Abitani

Clivet S.p.A., Feltre, Italy

## D4: Refrigerant Safety | ESJ 1215

Chair: Andy Pearson

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## 1285 The Importance of Engineering Safe, Efficient, and Low Carbon Use of Natural Refrigerants

Stephen Oliver Andersen\* (1), Suely Carvalho (2) Sean Dennis (1) (technical editor)

1: Institute for Governance & Sustainable Development, USA; 2: Independent Consultant, São Paulo, SP, Brazil

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## 1239 Closing Knowledge Gaps in R290 Heat Pump Safety Evaluation

Thore Oltersdorf (1), Timo Methler (1), Daniel Colbourne (2), Martin Kreuz (1), Hannes Fugmann\* (1)

1: Fraunhofer ISE, Germany; 2: Re-phridge Ltd., United Kingdom

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## 1207 Investigation of Refrigerant Leakage Behavior Prediction Using Machine Learning

Ryoutarou Yokono\*, Hirohisa Ohama, Masashi Kamada, Kazutaka Hori

Daikin Industries, LTD., Japan

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## 1287 Critical Aspects in CFD-Modelling of R-290 Leakages

Jafar Esmaeelian\*, Rahmatollah Khodabandeh, Björn Palm, Monika Ignatowicz

KTH Royal Institute of Technology, Sweden

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## 1141 Comparison of Laminar vs RANS and Large-Eddy Simulation (LES) Turbulent Flow Models for the Analysis of R290 Leakage

Marine Fayolle (1), Hironori Tsunoyama\* (1), Takahiro Aoki (1), Kentaro Nakagawa (2), Takahiko Hashimoto (2), Akira Hiwata (2)

1: Panasonic Holdings Corporation, Technology Division; 2: Panasonic Corporation, Heating and Ventilation AC Company

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## 1119 Feasibility Study of a New Refrigerant Leak Detection Algorithm Using Transient Simulation

Kosuke Kibo\*, Keisuke Tanimoto, Takahiro Ozaki

Daikin Industries, Ltd., Japan

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## TUESDAY, AUGUST 13

3:30 PM - 5:30 PM

## A5: Systems 3: Natural Refrigerants | ESJ 0202

Chair: Seontae Kim

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## 1129 Assessment of CO<sub>2</sub>/R600a Blends in Parallel Compression Refrigeration Systems: A Focus on Fractionation

Manel Martínez Angeles\* (1), Laura Nebot Andrés (1), Fabio Petruzzello (2), Angelo Maiorino (2), Ciro Aprea (2), Ramón Cabello (1), Rodrigo Llopis (1)

1: University Jaume I, Spain; 2: Università degli Studi di Salerno, Italy

# Technical Sessions



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**1150** **SophiA: Sustainable Off-Grid Solutions for Pharmacies and Hospitals in Africa – Laboratory and Field Test Data of Three Stage Cascade System with CTES**

Oliver Schmid\*

*University of applied sciences Karlsruhe, Germany*

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**1307** **Decarbonizing District Energy: Leveraging CO2 Heat Pumps at UBC Okanagan**

Parham Eslami Nejad\*

*Vitalis, Canada*

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**1303** **Deployment of R290 in Heat Pump Water Heaters and Implications for Decarbonization**

Kashif Nawaz\*, Jian Sun

*Oak Ridge National Lab, USA*

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**1188** **Comparative Study of Heat Storage System in Water Vapor Compression Heat Pump for Industrial Processes**

Seon Tae Kim\* (1), Steffen Klöppel (1), Eberhard Nicke (1), Katamala Malleswararao (2), Marc Linder (2), Panagiotis Stathopoulos (1)

*1: Institute of Low-Carbon Industrial Process, German Aerospace Center (DLR); 2: Institute of Engineering Thermodynamic, German Aerospace Center (DLR)*

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**1114** **Hydrocarbons in Heat Pumps: An Experimental Investigation on the Influence of an Internal Heat Exchanger**

Christoph Höges\*, Philipp Roy, Kaj Neumann, Christian Vering, Dirk Müller

*RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate, Aachen, Germany*

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**1124** **Developments in Low Charge Ammonia Refrigeration for Food Processing and Storage**

Andy Pearson\*

*Star Refrigeration Ltd, United Kingdom*

## **B5: Systems 4: HTHP 1 | ESJ 1224**

Chair: Steven Lecompte

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**1121** **Simulation of High Temperature Heat Pump Performance**

Thomas Lund\*

*Danfoss A/S, Denmark*

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**1226** **Analysis of Two-Stage High-Temperature Heat Pump Cycles for Steam Generation Using Hydrocarbons as Refrigerants**

Abdelrahman Hassan (1,2), Jorge Paya (1), Emilio Navarro Peris\*(1)

*1: Universitat Politècnica de Valencia, Spain, Mechanical Power Engineering Department, Faculty of Engineering, 2: Zagazig University, Zagazig, Egypt*

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**1202** **Digital Twin of a Full-Scale Industrial Heat Pump Producing Steam Above 140°C**

Ali Can Ispir\* (1), Gustavo Otero Rodriguez (2), Wouter de Vries (2), Michel Speetjens (1)

*1: Eindhoven University of Technology, Eindhoven, 5600MB, The Netherlands; 2: Netherlands Organisation for Applied Scientific Research (TNO), Sustainable Technologies for Industrial Processes, Energy & Materials Transition Unit, Petten, The Netherlands*

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**1208** **Performance Comparison of a Lab and Industrial Scale Propane-Butane Cascade Heat Pump**

Marco Bless\*, Till Holmes, Ole Marius Moen, Petter Neksa, Christian Schlemminger

*SINTEF Energy Research, Norway*

# Technical Sessions



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## 1199 Evaluation of Pentanes as Refrigerants for Heat Pumps with Sink Temperatures above 130°C

Sebastian Benkert\*, Hannah Teles de Oliveira, Ursula Wittstadt, Hannes Fugmann, Lena Schnabel  
*Fraunhofer ISE, Germany*

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## 1251 Low-Charge Isobutane Heat Pump for Medium and High-Temperature Applications

Klas Andersson\* (2), Viktor Ölen (3), Björn Palm (1), Jan-Erik Nowacki (4)  
*1: KTH Royal Institute of Technology, Sweden; 2: SweTemp; 3: SKVP; 4: Nowab*

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## 1111 Solution Examples for Cooling and Process Heating in Industrial Applications

Ivan Rangelov\*  
*Danfoss A/S, Denmark*

## C5: Workshop: Decarbonization Through Adopting Low-GWP Refrigerants | ESJ 1202

Chair: Xudong Wang

**3:30–4:00 pm** Katharine Kaplan | DOE's Future of Refrigerants R&D and Voluntary Market Efforts to Support Ultra Low GWP Refrigerants

**4:00–4:40 pm** Yosr Allouche & Silvia Minetto | ENOUGH Project for Decarbonization of the Food Chain: How to Reach Net Zero by 2050

**4:40–5:10 pm** M S Dasgupta | On-Board Refrigeration Using Propane for Improved Fish Preservation in Small Fishing Boats

**5:10–5:30 pm** Olivier Schmid | Decarbonization Through Adopting Low-GWP Refrigerants in the SophiA Project in Africa

## D5: Thermal Management & CFD Analysis | ESJ 1215

Chair: Andy Pearson

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## 1246 The Development of the CO<sub>2</sub> Cooling Plants for the Upgrade Silicon Detectors of ATLAS and CMS at CERN

Bart Verlaet\*, Paolo Petagna, Łukasz Zwalinski, Jerome Daguin, Viren Bhanot, Loïc Davoine, Krzysztof Sliwa, Yann Herpin, Cedric Landraud, Dani Teixeira, Michał Zimny, Szymon Galuszka  
*CERN, Switzerland*

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## 1103 Simulating the Startup and Backup Operation of Next Generation CO<sub>2</sub> Pumped-Loop Cooling Systems

Amandla Power Mvimbi (1,2), Bart Verlaet (1), Daniella Ida Teixeira (1), Loïc Davoine (1), Łukasz Zwalinski (1), Michal Zbigniew Zimny (1), Paolo Petagna (1), Viren Bhanot\* (1)  
*1: CERN, Switzerland; 2: University of Cape Town, Electrical Engineering Department, South Africa*

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## 1235 Applying Krypton as Refrigerant for Cooling of Future Particle Detector Trackers at CERN

Luca Contiero\* (1,2), Bart Verlaet (1), Armin Hafner (2), Krzysztof Banasiak (2), Yosr Allouche (2), Paolo Petagna (1)  
*1: European Organization for Nuclear Research, Geneva, Switzerland; 2: Norwegian University of Science and Technology, Trondheim, Norway*

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## 1185 Open-Source CFD Modelling of Two-Phase CO<sub>2</sub> Ejectors

Negar Alvandifar\* (1,2), Ehsan Mahravan (1), Jóhannes Kristófersson (3), Kim Gardø Christensen (2), Pourya Forooghi (1)  
*1: Department of Mechanical and Production Engineering, Aarhus University, Aarhus, Denmark; 2: FENAGY A/S, Lystrup, Denmark; 3: Danish Technological Institute, Gregersensvej 1, Taastrup, Denmark*

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## 1139 CFD Modeling of Crystallization During the Freeze Concentration Process

Muhammad Umar Khan\*, Ignat Tolstobrov, Trygve M. Eikevik  
*Norwegian University of Science and Technology, Norway*

# Technical Sessions



## WEDNESDAY, AUGUST 14

8:00 - 10:00 AM

### A6: Systems 5: District Heating | ESJ 0202

Chair: Hatef Madani Larijani

#### 1172 Heat Recovery and Heat Pump Applications using CO<sub>2</sub> as Refrigerant

Mazyar Karampour (1), Torben Funder-Kristensen (2)

1: Danfoss Sweden AB, System Engineering and Solutions; 2: Danfoss Denmark A/S, Industrial Affairs

#### 1166 Theoretical Investigations on Using High-Temperature Heat Pumps in Combination with District Heating Networks

Haochen Wang\*, Dimitri Nefodov, Markus Richter, Thorsten Urbaneck

Chemnitz University of Technology, Germany

#### 1142 Under Variable Conditions: Investigating the Off-Design Performance of Natural Refrigerants in Heat Pumps

Sebastian Hubert Ostlender\*, Christoph Höges, Christian Vering, Dirk Müller

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#### 1256 Refrigerant Selection for District Heating's Large-Scale Heat Pumps

Görkem Balyaligil\* (1,2), Samer Sawalha (2), Erik Skoglund (3)

1: Siemens Energy; 2: Royal Institute of Technology (KTH); 3: Stockholm Exergi AB

#### 1152 Optimizing Surplus Heat Utilization: A Case Study on CO<sub>2</sub>-Based Supermarket Refrigeration Cycle with District Heating Integration in Southern Denmark

Sotirios Thanasoulas\*, Ekaterini E. Kriezi, Mark Sever, Lars M. Jessen

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### B6: Systems 6: HTHP 2 | ESJ 1224

Chair: Björn Palm

#### 1118 Experimental Investigation of Oil Free Absorption-Compression Heat Pumps with Liquid Injection Screw Compressor for high Temperature Applications

Khalid Hamid\*, Shuai Ren, Ignat Tolstorebrov, Armin Hafner, Trygve M. Eikevik

Department of Energy and Process Engineering, Norwegian University of Science and Technology, Trondheim, Norway

#### 1277 A Comparison of Simplified Modeling Approaches and Simulation Quality of an Industrial R717-HTHP

Michael Wernhart\*, Manuel Verdnik, Gerhard Pertiller, René Rieberer

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#### 1205 High-Temperature CO<sub>2</sub> Heat Pump Integration for Milk Powder Spray Drying

Lana Kong\* (1), Timothy G. Walmsley (1), James K. Carson (1), Steffen Klöppel (2), Florian Schlosser (3), Donald J. Cleland (4)

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#### 1237 Carbon-Neutral Steam Supply for a Chemical Plant: Simulation of the Integration of a High-Temperature Heat Pump Using CO<sub>2</sub>

Lukas Steinberg\* (1), Stefan Glos (2), Tobias Korte (3), Valentin Bertsch (3), Roland Span (1)

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# Technical Sessions



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## 1210 Development and Testing of a Steam Compression Heat Pump for Low-Grade Waste Heat Recovery

Miguel Ramirez\* (1), Gustavo Otero Rodriguez (1), Daan Scheepens (2), Geert van de Weijer (2), Simon Spoelstra (1)

1: TNO; 2: Standard Fasel, The Netherlands

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## 1229 Design of a High-Temperature Heat Pump Providing Heat up to 200 °C

Elias Vieren\* (1), Kenny Couvreur (1), Michel De Paepe (1,2), Steven Lecompte (1,2)

1: Ghent University - Department of Electromechanical, Systems and Metal Engineering, Ghent, Belgium; 2: FlandersMake, FlandersMake@UGent Core lab EEDT-MP, Leuven, Belgium

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## C6: Field Testing | ESJ 1202

Chair: Giovanni Cortella

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## 1176 Design and Experimentation of a New CO<sub>2</sub> Air Conditioning System

Yu Wei Fan (1,2), Quan Jiang Wang (1), Yi Zhou Wang (2), Jian Hui Kang (1), Jia Liu (2,3), Xiao Long Li (1), Jian Guo Yang (1), Xin Rong Zhang\* (2,3)

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## 1225 Novel Large Scale Combined Heating and Cooling CO<sub>2</sub> System

Pierre-Jean Delêtre (1), Jóhannes Kristofferson\* (1), Arvydas Latvenas (1), Jesper Weinkauff Kristoffersen (1), Henrik Andersen (2), Kim Gardø Christensen (2)

1: Teknologisk Institut, Denmark; 2: Fenagy, Denmark

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## 1175 Energy Saving of a CO<sub>2</sub> Transcritical System in a Cold Storage: Combination of Freezer Floor Heating & Gas Cooler Subcooling

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## 1195 Field Data of a R744 Unit Satisfying Thermal Requirements of a Resort in the South Mediterranean Climate

Silvia Minetto\* (1), Francesco Fabris (1), Sergio Marinetti (1), Luca Bisetto (2), Sergio Giroto (2), Antonio Rossetti (1)

1: National Research Council, Construction Technologies Institute, Italy; 2: Enex Srl, Italy

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## 1170 Performance Testing of CO<sub>2</sub>-NH<sub>3</sub> Cascade Tunnel Freezer for Seafood Processing

Sumit Kumar (1), B. S. Arun (2), Murali S (2), George Ninan (2), Maddali Ramgopal (3), Manoj Samuel (4), Lukas Köster\* (5), Jan Bengsch (5), Kristina Norne Widell (5), Armin Hafner (6), Saju George (7), Kolliyil Ashraf Hashmin (8)

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## 1163 Performance Assessment of Low Charge Ammonia Refrigeration in a High Bay Automated Warehouse

Andy Pearson\*

Star Refrigeration Ltd, United Kingdom

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# Technical Sessions



## D6: Market Analysis | ESJ 1215

Chair: Marco Azzolin

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### 1283 Compilation of Equipment Maps for Refrigerators and Heat Pumps Using Natural Working Fluid in Japan

Katsumi Hashimoto\* (1,4), Yohei Kayukawa (2,4), Kiyoshi Saito (3,4), Yoichi Miyaoka (3,4)

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### 1295 Full Conversion to Natural Refrigerants - Feasible and Likely to Happen?

Petter Nekså\*

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### 1262 Heat Pump Product and Market Data - Tools and Analysis

Thore Oltersdorf, Elvin Garashli, Hannes Fugmann\*, Lena Schnabel

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### 1224 Designing a CO2 Heat Pump Satisfying the Ecodesign Requirements: Challenges and Solutions

Pierre-Jean Delètre\* (1), Jóhannes Kristofferson (1), Christian Heerup (1), Troels Stevns Pedersen (1), Arvydas Latvenas (1), Jesper Weinkauff Kristoffersen (1), Henrik Andersen (2)

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### 1189 Outlining the Requirements For Propane-Based Heat Pump Solutions for Existing Multi Family Houses

Björn Nienborg, Beatrice Rodenbücher, Annette Uhl, Hannes Fugmann\*, Peter Engelmann

Fraunhofer Institute for Solar Energy System (ISE), Germany

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### 1171 Market Trends and Drivers in New Product Development of Natural Refrigerant Components

Torben Funder-Kristensen\* (1), Mazyar Karampour (2)

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## WEDNESDAY, AUGUST 14

10:30 AM - 12:00 NOON

## A7: Systems 7: Transport | ESJ 0202

Chair: Tobias Sienel

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### 1294 Real Unit Double Expansion CO2 Public Transport Application Heat Pump Simulation Model Comparison With Single Expansion Alternative Model

Pavel Houdek\*, Martin Galansky

Trane Technologies, Czech Republic

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### 1233 Effects of a R744 Cooling Unit Design on the Overall Energy Performance of a Refrigerated Vehicle

Francesco Fabris\* (1), Wasim Shah (2), Sergio Marinetti (1), Silvia Minetto (1), Antonio Rossetti (1)

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### 1159 R744 Mass Transit Mobile AC and HP System in Bus Application

Alexander Schmig\*, Michael Petersen, Steve Kujak, Pavel Houdek, Michal Kolda, Martin Galansky

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# Technical Sessions



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## 1153 Assessment of Natural Refrigerants for Thermal Management in Battery-Electric Long-Distance Buses

Jan Friedrich Hellmuth\* (1), Markus Pollak (1,2), Andreas Schulte (1), Wilhelm Tegethoff (1,2), Jürgen Köhler (1)  
1: TU Braunschweig, Germany; 2: TLK Thermo GmbH, Braunschweig, Germany

## B7: Measuring Methods | ESJ 1224

Chair: Phillip Johnson

---

## 1162 Natural or Synthetic Refrigerants: Does the Lubricant Care?

Joe Karnaz\* (1), Manuel Munoz (2), Liz Dixon (2), Jun Liu (3)  
1: Shrieve Chemical Products, LLC, USA; 2: Shrieve Products International; 3: Shrieve Chemical Shanghai

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## 1140 Refrigeration Machine with Accurate Inline Sensors for Measuring Thermophysical Properties of Oil-Refrigerant Mixtures

Caner Cizmaz\*, Jonathan Laun, Xiaoxian Yang, Markus Richter  
Applied Thermodynamics, Chemnitz, Germany

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## 1123 Good Vibes for Heat Pumps: Towards Refrigerant Charge Indication with Vibration Sensors

Tim Klebig\*, Luca Hummel, Philipp Ostmann, Jonas Klingebiel, Christian Vering, Dirk Müller  
RWTH Aachen University, Germany

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## 1247 Investigation of Indirect Measuring Methods For Evaluating The Energy Efficiency of a Low Temperature Refrigerating System Under Different Operating Conditions

Stefan Hudjetz\*, Daniel Pfeiffer, Martin Becker  
Biberach University of Applied Sciences, Germany

## C7: Operations & Controls | ESJ 1202

Chair: Jonas Kjær Jensen

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## 1232 Retrofitting Potential of R744 Heat Pump/Chiller for a Multispecialty Hospital

Simarpreet Singh\*, Sarun Kumar Kochunni, Armin Hafner  
Norwegian University of Science and Technology, Norway

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## 1117 Preliminary Study on Fault Detection in Gas Coolers for Transcritical CO<sub>2</sub> Refrigeration Systems

Milad Morid Zadeh\* (1), Roozbeh Izadi-Zamanabadi (2,3), Hossein Ramezani (1), Paride Gullo (1)  
1: University of Southern Denmark; 2: Danfoss A/S; 3: Aalborg University

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## 1300 A Numerical Investigation of the Dynamic Responds of Solar Direct Drive Refrigerators Under Different Control Strategies

Jonas Kjær Jensen (1), Per Henrik Pedersen (2), Ivan Katic (2)  
1: Technical University of Denmark, Denmark; 2: Danish Technological Institute

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## 1151 Identification of Refrigeration Load Parameters for Display Cabinets from Monitoring Data

Andreas Schulte\* (1), Peder Bacher (2), Christian Heerup (3), Wilhelm Tegethoff (1), Benjamin Zühlsdorf (3), Juergen Koehler (1)  
1: TU Braunschweig, Germany; 2: DTU Compute, Denmark; 3: Danisch Technological Institute

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## 1181 Simulation and Test Results of a Innovative CO<sub>2</sub> Residential Monoblock Heat Pump for Domestic Hot Water

Claudia Fiabane\* (1), Federico Virgilio (1), Mirko Buti (1), Federico Simoni (1), Linda Padoan (1), Simone Piovesan (1), Armin Hafner (2), Engin Söylemez (2), Mihir Mouchum Hazarika (2)  
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# Technical Sessions



## D7: Not-In-Kind 2 | ESJ 1215

Chair: Hirofumi Daiguji

### 1174 Energy, Environmental, and Economic Evaluations of Electrochemical Looping Heat Pump Technology

Mingjie Zhu\* (1), Jinwoo Oh (1), Junyoung Kim (2), James E. Braun (1), Eckhard A. Groll (1), Davide Ziviani (1)

1: Ray W. Herrick Laboratories, West Lafayette, IN, USA; 2: National Renewable Energy Laboratory, Golden, CO, USA

### 1291 Experimental and Numerical Study on the Performance of a MOF-Coated Heat Exchanger Under Pressure Swing Adsorption

Ming-Hsuan Hu (1), Jubair A. Shamim (1), Gunjan Auti (1), Fabio Boccamazzo (1), Paris Pasqualin (1), Wei-Lun Hsu (1), Hirofumi Daiguji\* (1), Masaki Tanaka (2), Eiji Kumakura (2), Takuro Yamada (2), Yoshio Oritani (2)

1: University of Tokyo, Japan; 2: Daikin Industries, Ltd., Japan

### 1164 Optimal Thermoelectric Heat Pump Design to Efficiently Perform the Power-To-Heat Process of a Thermal Energy Storage System

Patricia Aranguren\*, Ivan Lerga, Irantzu Erro, Alvaro Casi, Antonio Rodriguez, Alvaro Martinez

Public University of Navarra, Spain

### 1113 A Novel Heat Pumping Cycle in a Rotation Heat Pump for Latent Process Heat Supply Using Sensible Heat Sources

Gerald Zotter\*, Bernhard Adler, Andreas Längauer

ECOP Technology GmbH, Austria



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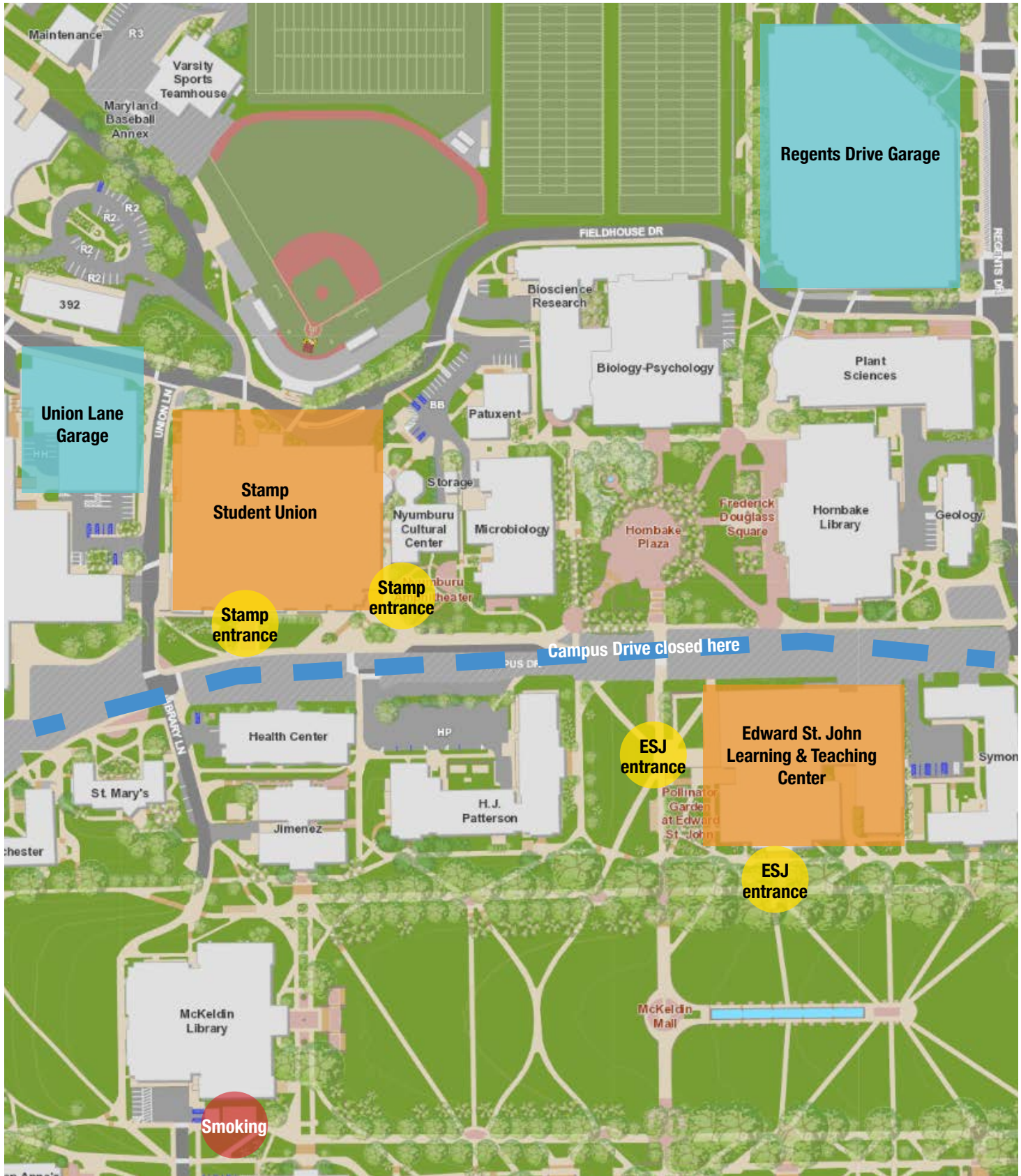


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# Campus Map

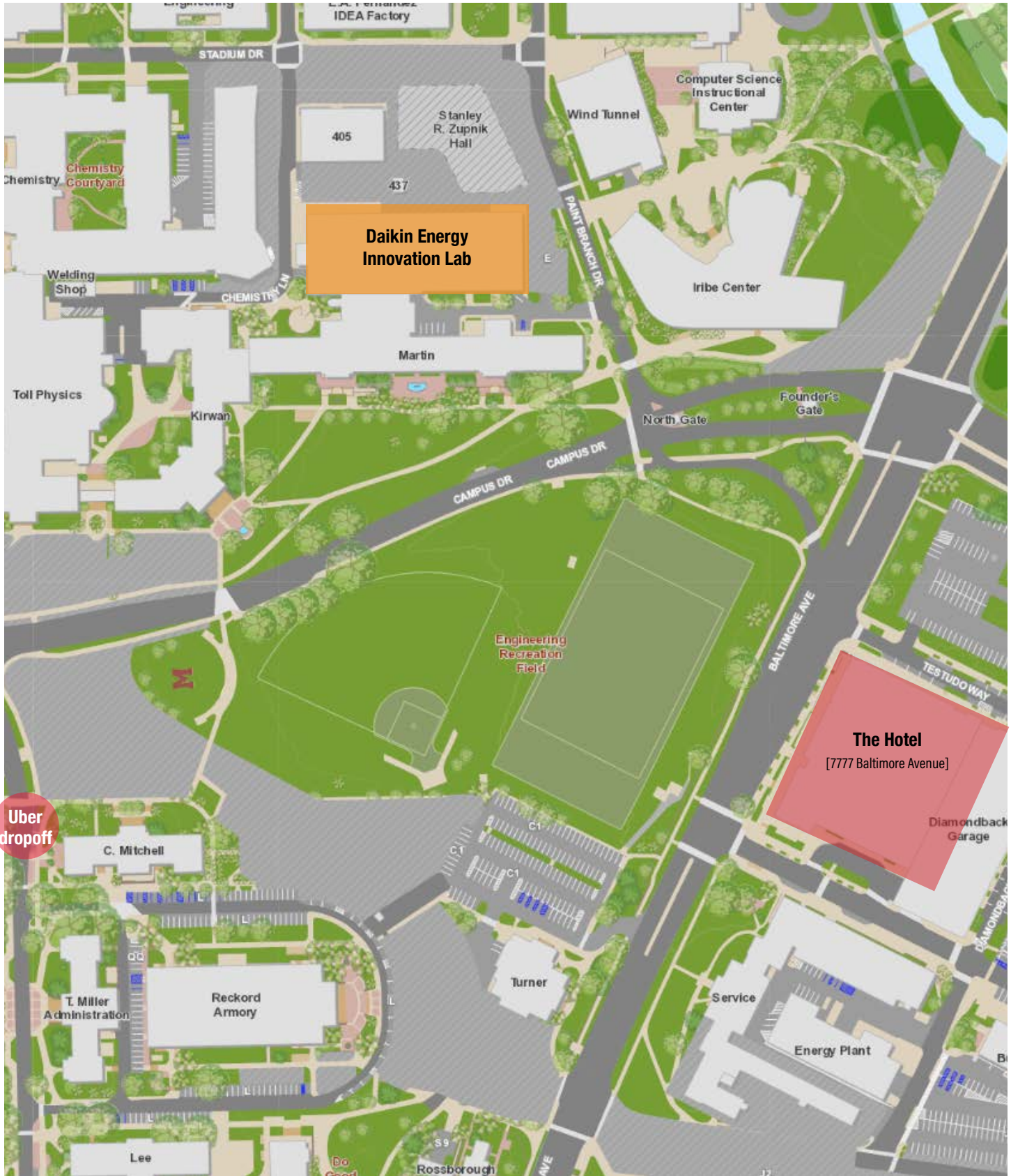
Dynamic UMD campus map

College Park Marriott Hotel



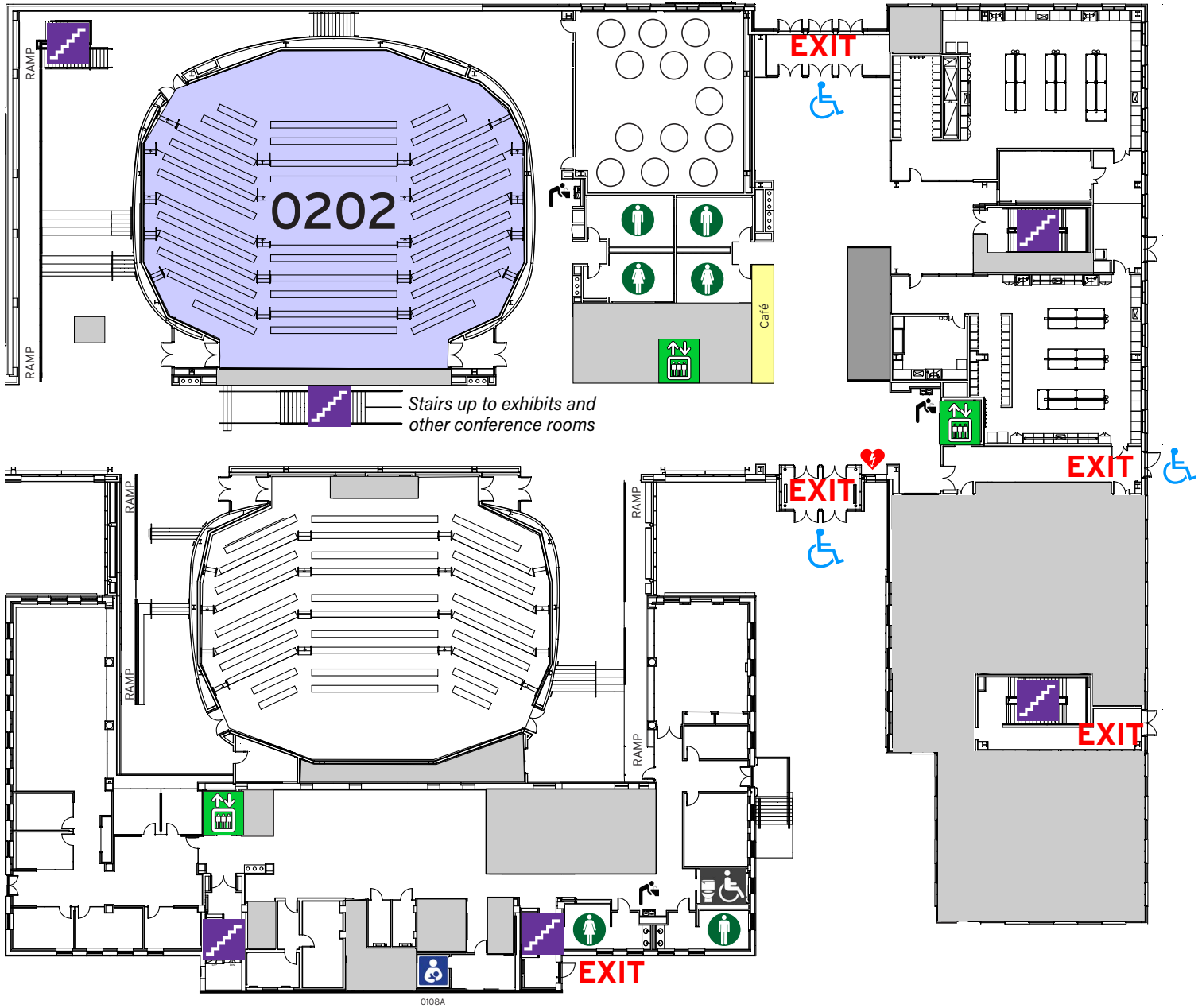


# Campus Map

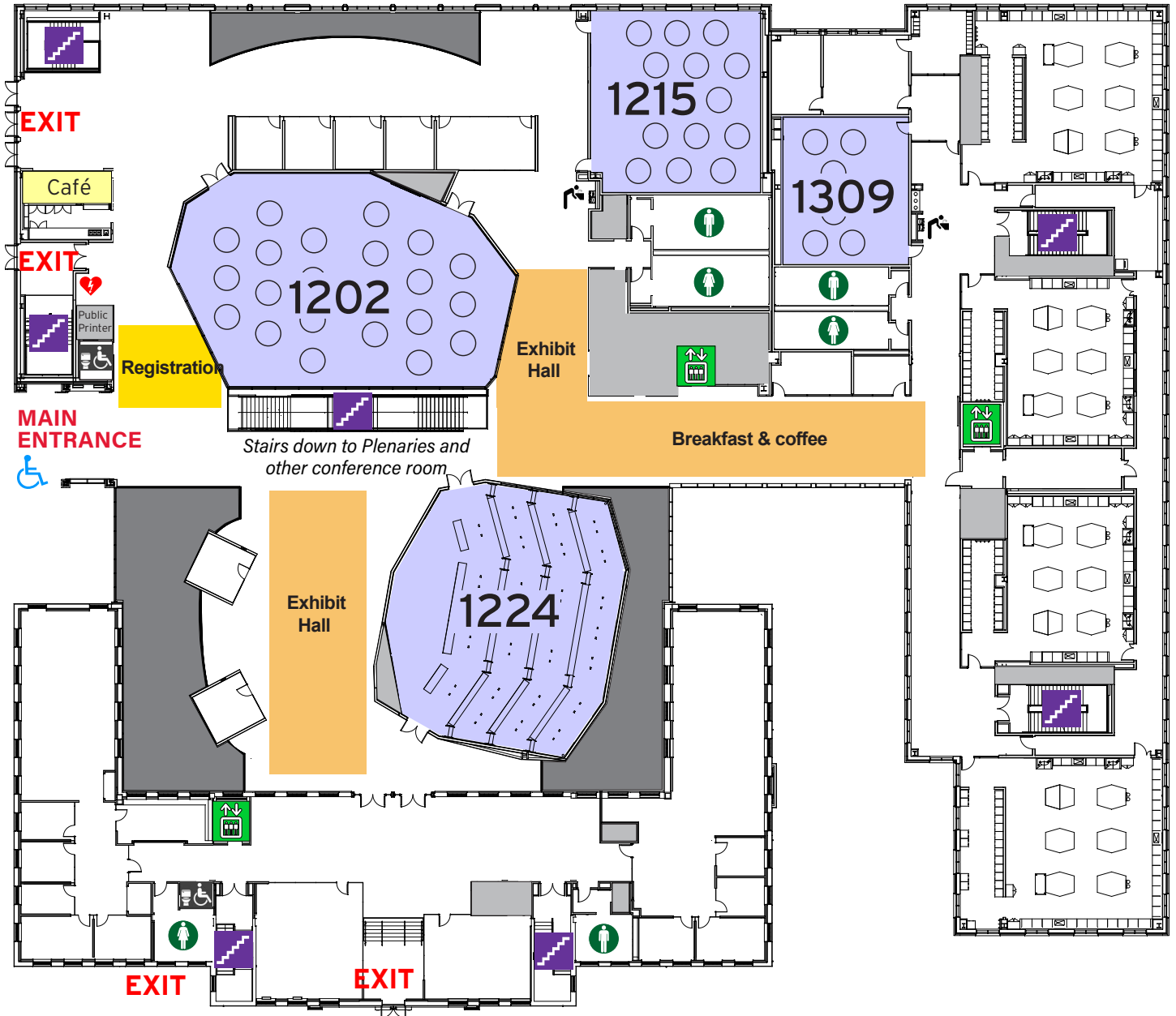


↑  
Cambria  
Hotel

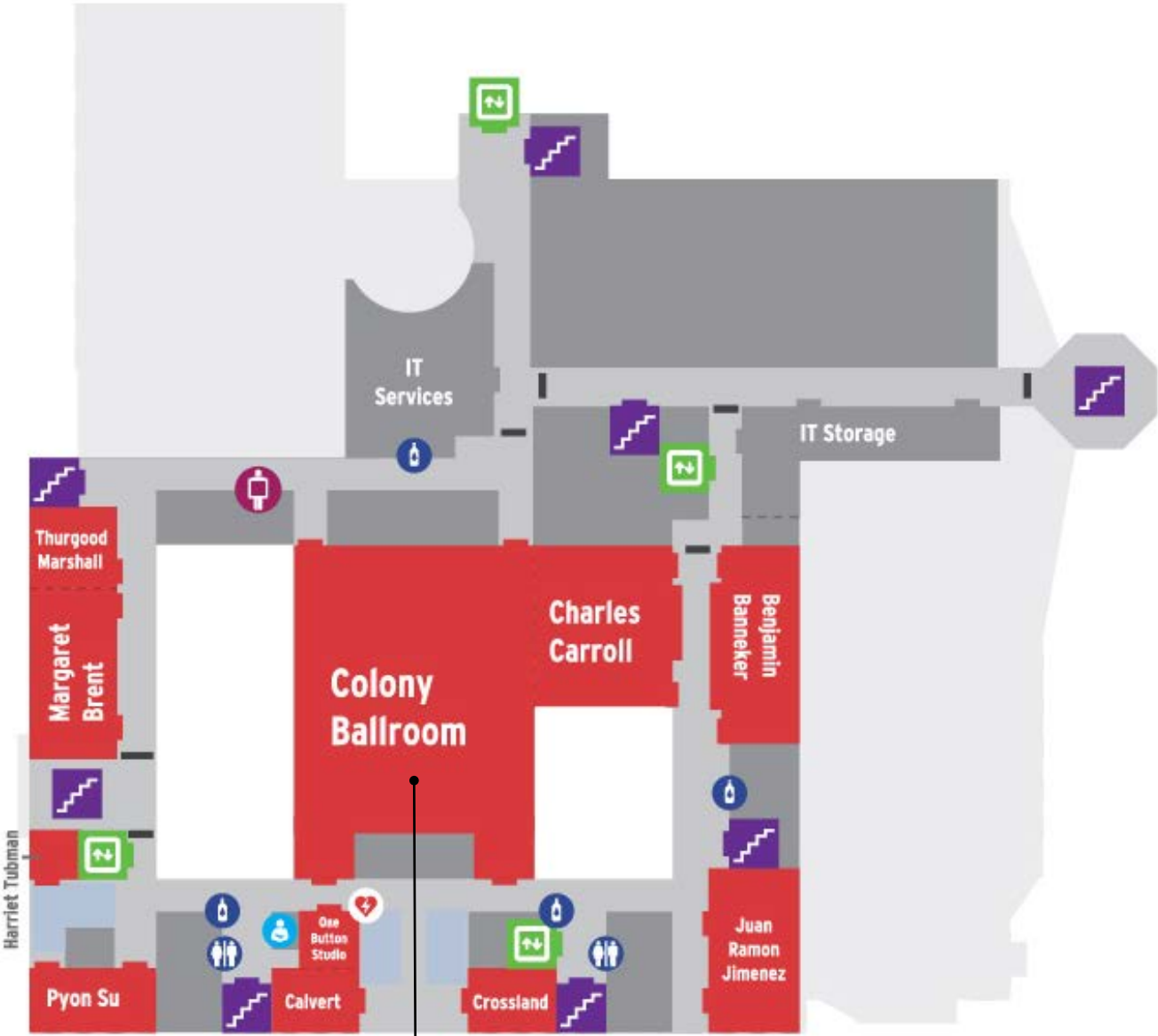
GROUND FLOOR  
Edward St. John Learning and Teaching Center  
4131 CAMPUS DRIVE



FIRST FLOOR  
Edward St. John Learning and Teaching Center  
4131 CAMPUS DRIVE



**SECOND FLOOR**  
**Stamp Student Union**  
**3972 CAMPUS DRIVE**



Lunches and the Conference Banquet will be offered in the Colony Ballroom in the Stamp Union.

# General Information



## Transportation to the Conference

**By plane:** The airports nearest to College Park are Baltimore/Washington International (25 miles/40 km), Reagan National (16 miles/26 km) and Dulles International Airport (37 miles/60km).

**By train:** Amtrak offers service to Union Station in Washington, DC (8 miles/14 km) and New Carrollton, Md. (6 miles/9 km).

**By Metro:** The Metrorail rapid transit system has a stop in College Park, with access from Union Station, Dulles International Airport and Reagan National Airport. A complimentary shuttle service is provided from the College Park Metro station to campus. The shuttle operates Monday-Friday during the summer. The schedule is available at <https://transportation.umd.edu/shuttle-um>.

## Campus Construction

The University of Maryland is undergoing construction detours due to work on the Purple Line light rail. Road closures include the section of Campus Drive near conference facilities. Please leave extra time to navigate the campus. For more information,

[See a map of vehicle detours](#)

[See a map of pedestrian detours](#)

## Rideshare Drop Off Point

If you plan to take an Uber, Lyft, or other rideshare service, please ask the driver to drop you off at the Clarence M. Mitchell, Jr. Building, 7999 Regents Dr., College Park, Md. The Edward St. John Learning and Teaching Center is only a three-minute walk away. Please walk along McKeldin Mall and enter the building at the McKeldin Mall entrance. Due to construction, access to the Campus Drive entrance to the building is unavailable.

## Parking

The Regents Drive Garage and Union Lane Garage are the two closest garages to the conference facilities. Rates are \$3 per hour, with a \$15 daily maximum. For details, see [Visitor Parking](#). Be aware that Campus Drive is closed between Regents Drive and the Benjamin Building, requiring detours to reach the Union Lane Garage, if you are entering the university at the Route 1 entrance. Parking in certain university surface lots (and in the lower levels of the Regents Drive Garage, not in "visitor parking" at the top) is free after 4 p.m., Monday-Friday, and anytime on Saturday and Sunday. Read signs closely.

## Conference Facilities

Conference activities will take place in two buildings:

**The Edward St. John Learning and Teaching Center (ESJ).** Registration, sponsor exhibitions, technical sessions, plenary sessions, breakfast and coffee breaks will be held in this modern space, equipped with the latest audiovisual technology. Plenary speeches will be on the ground level in Room 0202. All other events will be held on the first floor. See the schedule to locate the room for each session. Presenters are welcome to use Room 1309 to prepare for their presentations. Stop by the registration desk with any questions and for our "lost and found" area.

Food for Thought Cafe (open 8 a.m.-2 p.m.), on the first floor near the registration desk, serves Starbucks coffee, sandwiches, wraps and snacks. You're welcome to grab a seat in any public area to network, take a break or prepare for your presentation.

## The Adele H. Stamp Student Union (The Stamp).

Lunch will be served in the Colony Ballroom on the second floor of The Stamp on Monday, Tuesday and Wednesday. The conference banquet will be held there on Tuesday evening. These meals are included with your conference registration. The Stamp is conveniently located across the street from ESJ.

The Stamp offers a variety of guest services, including the University Book Store, two ATMs, a convenience store, copy and mail services, a food court, a movie theater, bowling and billiards. For help locating services, stop by the information desk on the first floor near the main entrance.



**Looking to see more of the campus?** Join us for a guided tour of the University of Maryland engineering labs that are developing eco-friendly HVAC&R technology. The tour is scheduled for Wednesday, August 14, at 1:00 p.m.-2:30 p.m., directly after the conference closing ceremony.

# General Information



## Accessibility

All conference facilities offer accessible entrances and amenities. [Read more about accessibility at ESJ](#) and [accessibility at The Stamp](#) online. If you have specific concerns, please notify us prior to the conference at [gl2024@umd.edu](mailto:gl2024@umd.edu) or stop by the registration desk during the conference.

## Smoking

Smoking is prohibited on campus, with the exception of four designated smoking areas. The closest smoking area is on the south side of McKeldin Library, to the left of the library's main entrance. Exit ESJ at the McKeldin Mall entrance and turn right to head toward McKeldin Library. The University of Maryland is a cannabis-free campus. You cannot use or possess any form of cannabis, including recreational or medical cannabis, anywhere on University of Maryland premises. This means no vaporizers, no edibles and no smoking.

## Dining

Your conference registration includes a welcome reception on Sunday with heavy hors d'oeuvres, mini desserts and a bar; lunch on Monday, Tuesday and Wednesday; and a conference dinner banquet on Tuesday evening. Optional dinner excursions are available on Monday evening. Check with the registration desk for more information.

In addition, Adele H. Stamp Student Union offers a [variety of options](#) for a quick meal or snack, including the Maryland Dairy, which offers University of Maryland-themed flavors like Fear the Turtle.

A vast array of [dining options](#) are located just off campus. Whether you're looking for sushi, tacos, salads, pizza or burgers, you'll find it along Baltimore Avenue (Route 1). College Park offers everything from quickservice dining options to upscale restaurants, including GrillMarx Steakhouse and Raw Bar in The Hotel at the University of Maryland.

## Pictures and Videotaping

Conference attendees may NOT take pictures or videos at any presentation without the consent of the author or presenter. An official photographer will take pictures during the conference. Attendees may NOT take pictures during the lab tours because the research is often highly sensitive.

## Conference Mobile App



We're excited to offer a mobile app to help attendees navigate the conference. Simply scan the QR code on this page and download the Whova app from the App Store or Google Play. Sign in or create an account by entering the email address you used to register for the conference. If you're having trouble joining our event, use Event Invitation Code: GL2024AtUMD.

The app provides easy access to the conference program, floor plans, plenary speaker bios and more. You can build your personal agenda and can network with other attendees through in-app messaging. The app is the best way to stay up to date and will alert you of any schedule changes or conference updates.

Gustav Lorentzen 2024 Conference

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## Internet Access

The University of Maryland provides two wireless networks for visitors to campus:

**Eduroam** If you use eduroam at your home institution, you are welcome to use the service to easily connect to the University of Maryland's Wi-Fi service.

**UMD-guest** If you are using a device that can receive SMS text messages, choose the umd-guest network option and follow the prompts to request an account.

# General Information



Wait for a text message. Access the text message to get your username and password, which can be used on up to three devices. [Guest Wi-Fi accounts](#) expire after 24 hours. You can repeat the process if you need additional time.

If you are unable to access the Internet using either of these two networks, please stop by the registration desk for assistance.

Attendees are encouraged to download offline maps for the DMV (DC, Maryland, Virginia) Area before leaving your home region.

Instructions can be found at:

[Apple Devices](#)

[Android Devices](#)

## Presentation Updates

If you have last minute changes to your presentation (different from what was uploaded into Conftool), please see your session chair to make arrangements to upload your new file.

## Conferences & Visitors Center

Stop by the University of Maryland Conferences & Visitor Services Welcome Desk for a warm Terrapin welcome. Friendly and informed staff members are available to provide parking information, directions and a campus map. The Welcome Desk is located in Turner Hall, 7736 Baltimore Ave, College Park, Md. Hours of operation are Monday – Friday, 8:00 a.m. – 5:00 p.m. Visitor information is also available [online](#).

## University Health Center

All campus guests may utilize services offered by the University Health Center (UHC). Office visits and laboratory services can be billed to many private insurance plans or paid for directly by the treated guest. (The UHC cannot bill Medicare, Medicaid, Kaiser Permanente and TRICARE Prime.) Arrangements for special medical needs (e.g., allergy injections, insulin storage) may be made by calling 301-314-8180. Due to construction, the Health Center entrance along Campus Drive is temporarily closed; entrance is available on the opposite side of the building.



## In Case of Emergency

If you see something, say something. Report crimes, hazards, traffic accidents, medical emergencies, chemical spills and other emergencies by dialing 911 or calling the University of Maryland Police Department at 301-405-3333. Report a fire by calling 911.

## Safety and Security

A full-service Department of Public Safety is located on Route 1 in the Pocomoke Building at 7569 Baltimore Ave., College Park, Md., just south of The Hotel at the University of Maryland. The department provides integrated safety and security services to the campus community. For additional security information, see <https://prepare.umd.edu/>.

## Exploring the Washington, D.C., Area

Metrorail (or Metro, as the locals call it) offers rail service throughout the Washington, D.C., metropolitan area, serving 98 stations in Maryland, Washington, D.C., and Virginia. A [campus shuttle](#) provides free transportation to the College Park Metro Station. A [map of the metro system](#) is in the visitors guide provided at the registration desk. For information on things to do in the area, see the [Washington DC Official Visitors Guide](#).

## Time Zone

During the conference, College Park, Md., will be on Eastern Daylight Time.



Gustav Lorentzen 2024 Conference

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