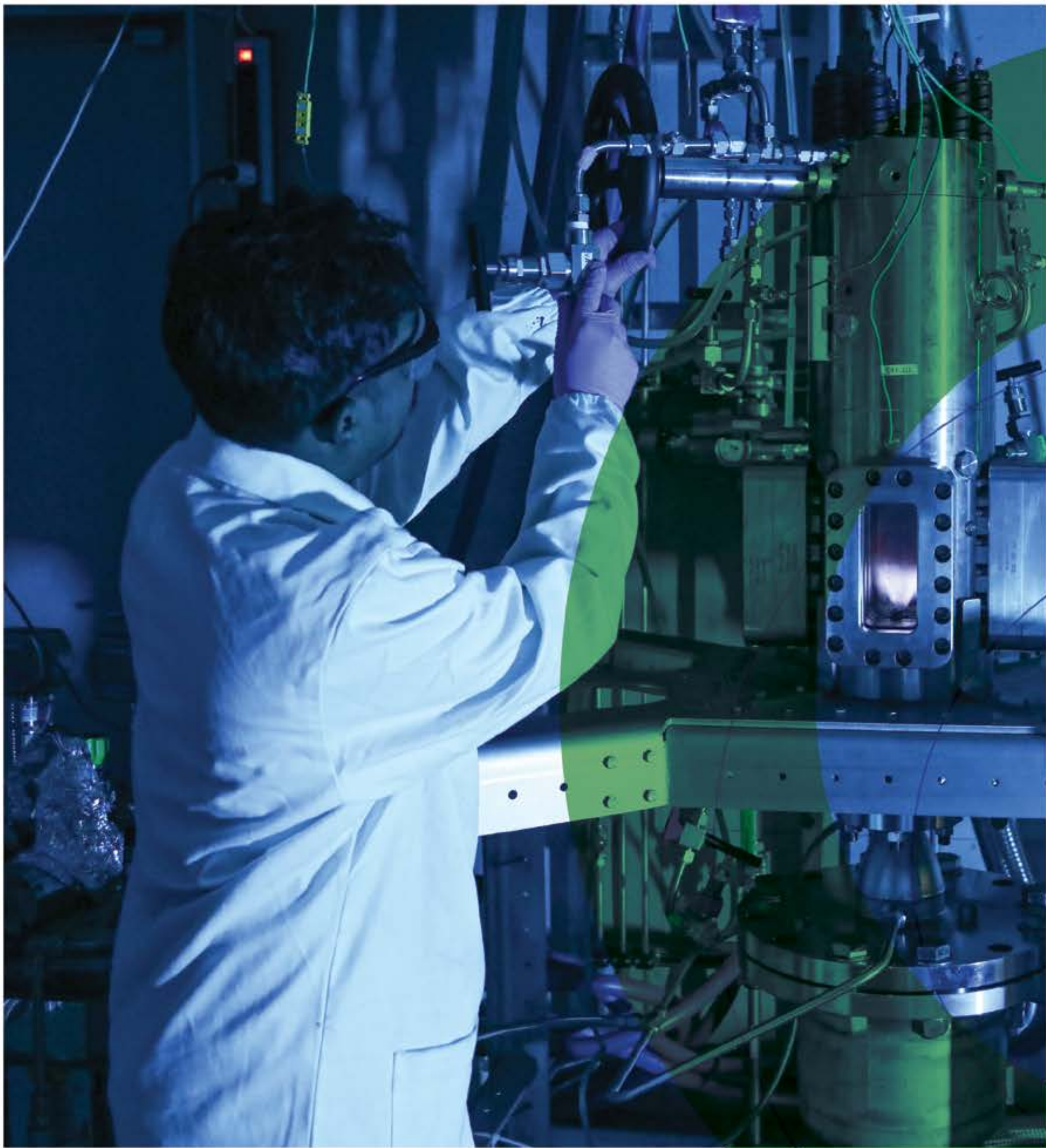
CCRC REPORT

Issue: Year end 2023



جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

CCRC

Repurposing the existing petrochemical refinery infrastructure to manufacture clean e-fuels derived from hydrogen and captured carbon dioxide is within reach.

This finding is one outcome from a suite of projects undertaken by the FLEET consortium, a multipartner collaborative research program initiated by KAUST and the Oil Sustainability Program of the Ministry of Energy of Saudi Arabia to reduce the transportation sector's carbon footprint.

See the *Cooperation to Fuel Change* article on page 9...

DIRECTOR'S NOTE

Dear Friends,

Another quarter has flown by, and the end of the year is upon us. It has been an exciting fall here at KAUST, with the much-anticipated release of the new Strategic Plan for the University. At the direction of our board of Trustees, we will come into close alignment with the Research, Development and Innovation Agency (RDIA) to more easily demonstrate and quantify the value we bring the Kingdom and help achieve the goals of Vision 2030 through accelerating technology up the Technology Readiness Level scale.

The CCRC has long been recognized as a major contributor to the Kingdom, and so we will do very well in the new environment. There will be some relatively minor changes for us, while other Centers will see major changes. It is very likely that we will change our name to CCRP, the Clean Combustion Research Platform, with minimal impact on our hard working and essential staff. These are still being negotiated, and I hope to be able to report more in our next newsletter. Suffice it to say the CCRC is very well positioned to bring in new projects without losing our distinct identity and working with a wide range of partners.

On another front, our FLEET consortium continues to thrive, adding Luberef Base Oil Company and Ferrari to the consortium recently. The CI's 40th International Symposium will be held in Milan in July, and our own Prof. Bassam Dally has the monumental task of being one of two Technical Program Co-Chairs. Submissions were due the 5th of December, and I fully expect us to be well-represented again this year.

I wish you all a wonderful holiday season and a happy and prosperous New Year.

Warm regards,
Bill

INSIDE THIS ISSUE

CCRC REPORT

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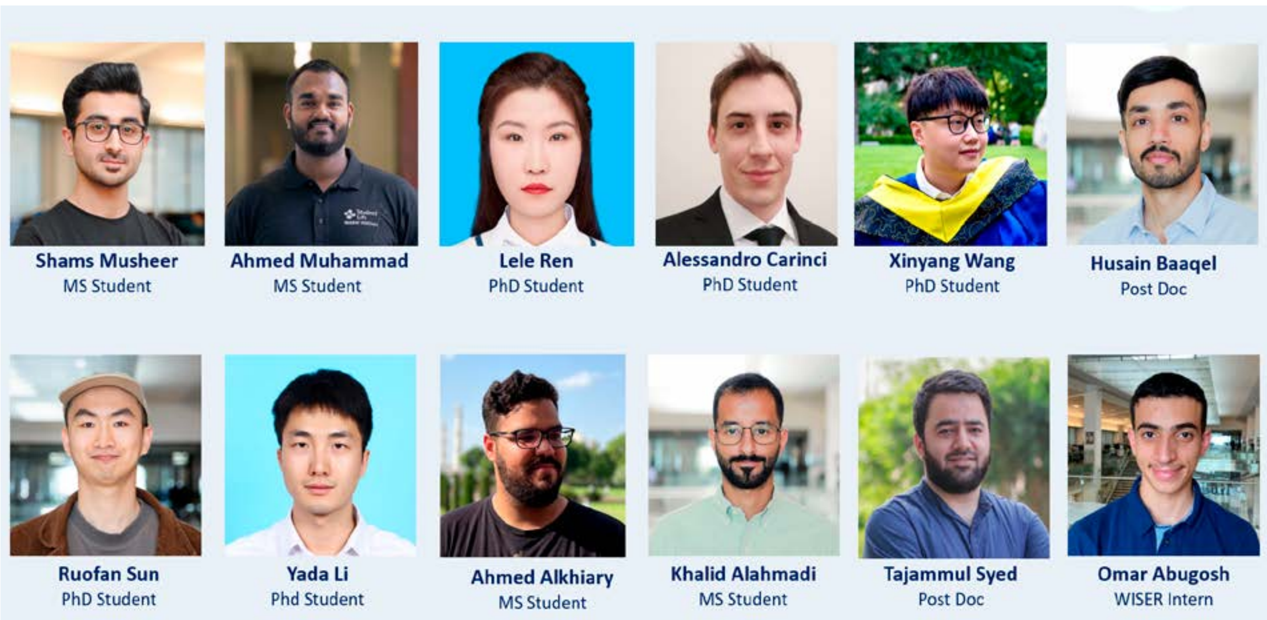
NEW TO THE CENTER-WELCOME!



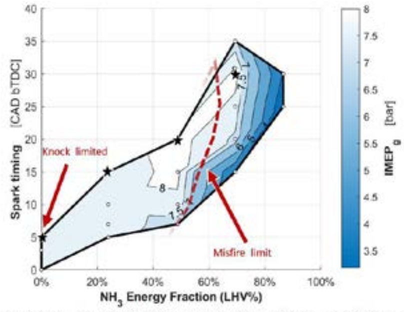


*Figure 6. Gross IMEP as a function of both spark timing and ammonia energy fraction. Black star: MBT timing (Combustion mode: **PC**)*

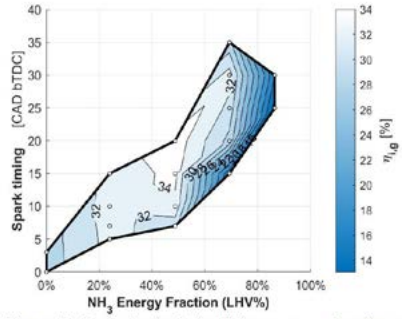


*Figure 7. Gross indicated efficiency as a function of both spark timing and ammonia energy fraction. (Combustion mode: **PC**)*

Congratulations to Fahad Almatrafi, a Ph.D student supervised by Prof. James Turner, for receiving the best paper award at the 2023 JSAE/SAE Powertrains, Energy and Lubricants International Meeting in Kyoto, Japan.

His paper is titled "Experimental Study of Fuel Mixture Limitations of Ammonia and Gasoline in a Passive Pre-Chamber Engine".

At ASPACC 2023 in Taiwan, awardees for the ASPACC 2021 were announced. The following stem from the CCRC:

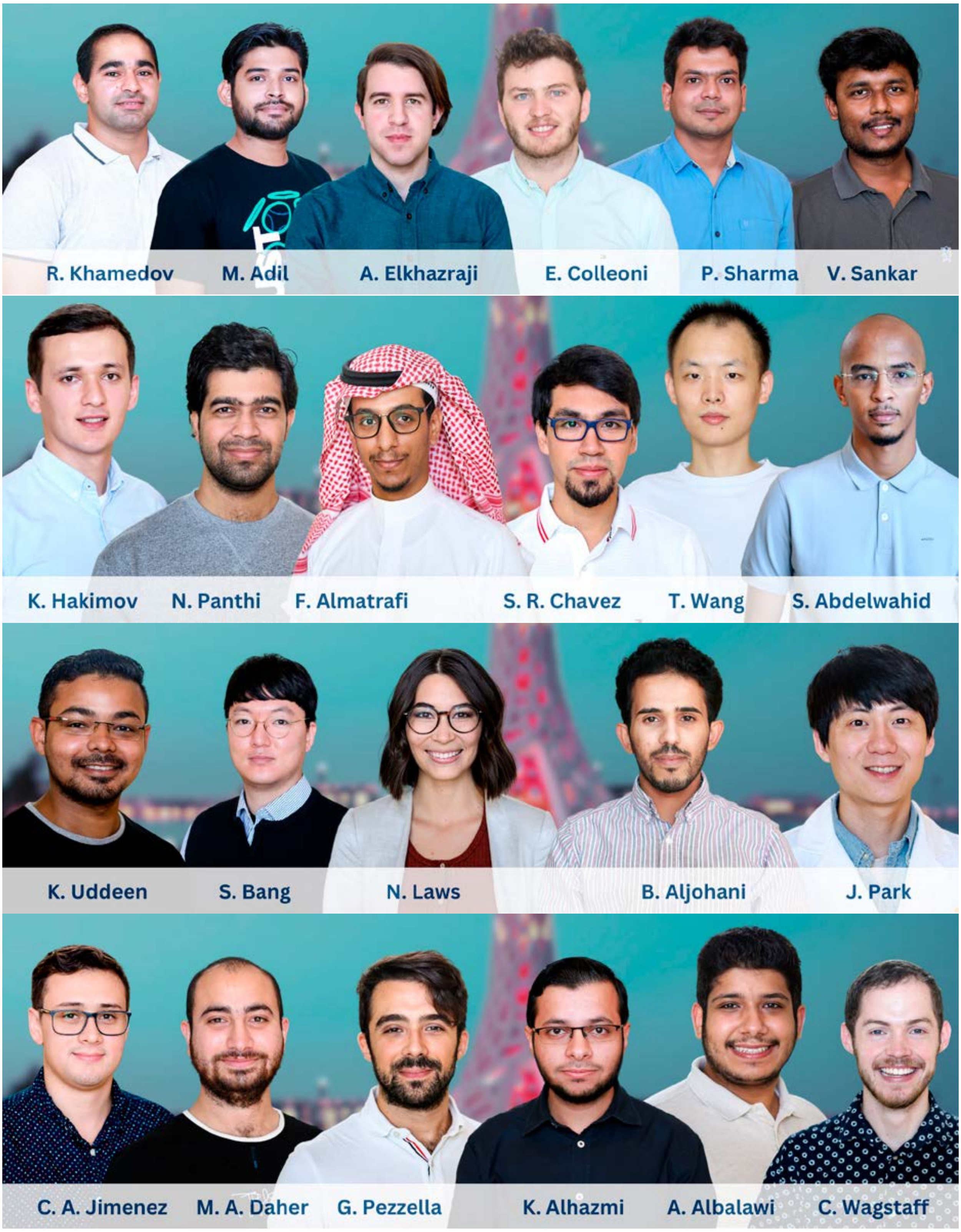
1 - Best paper award: supervised by Prof Hong Im. Title: A Priori Computational Assessment of Laminar Flame Speed Correlation in an Ultralean Prechamber Engine
Granted to all co-authors: Ghufran Alkhamis, Mickael Silva, Emre Cenker, Hong G. Im

2 - Best paper award: supervised by Prof Gaetano Magnotti and granted to all co-authors Guoqing Wang, Hao Tang, Chaobo Yang, Thibault F. Guiberti, William L. Roberts. Title: "Laser-induced fluorescence of NO in laminar nitrogen-diluted ammonia-hydrogen diffusion flames at high pressure."

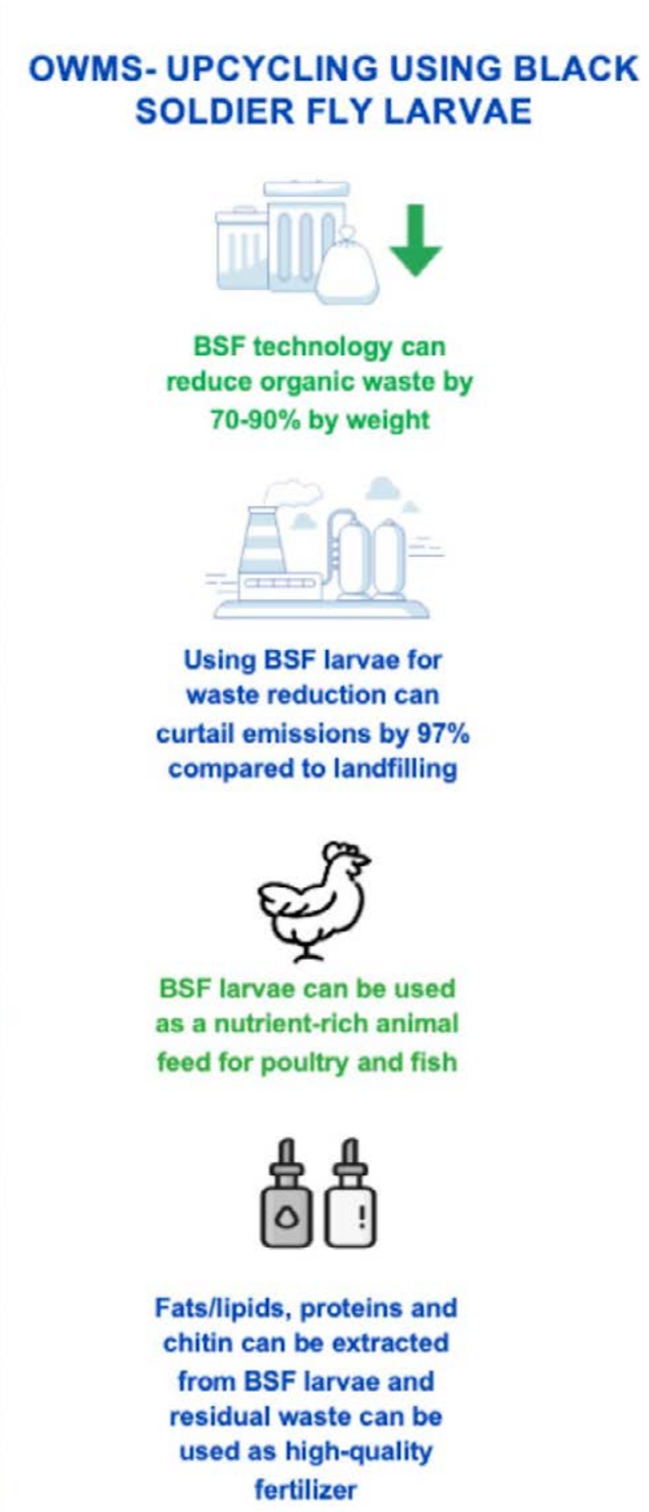
3 - Young investigator award: granted to Mickael Silva (Ph.D. under Prof Hong Im).

PSE Dean's Award '23

The Dean's Award is a recognition per program of high academic achievements as well as performance in the research lab. This prestigious award began last year.



OWMS start-up gaining recognition



Organic Waste Managment Solutions (OWMS), a startup led by Prof. Mani Sarathy, won second place in the StartSmart Competition, and was also selected as a finalist in the London Business School Startup Competition in the MENA region.

The OWMS team: Baqer Aljaman, Dr Ribhu Gautam, Shushant Giri, and Daniel Enebeli, created an innovative solution for organic waste management using black fly larva. The process has zero carbon footprint with an end result being marketable products to grow Saudi's circular economy. An important step in tackling the global waste crisis.

FLEET celebrates accomplishments in the transport sector

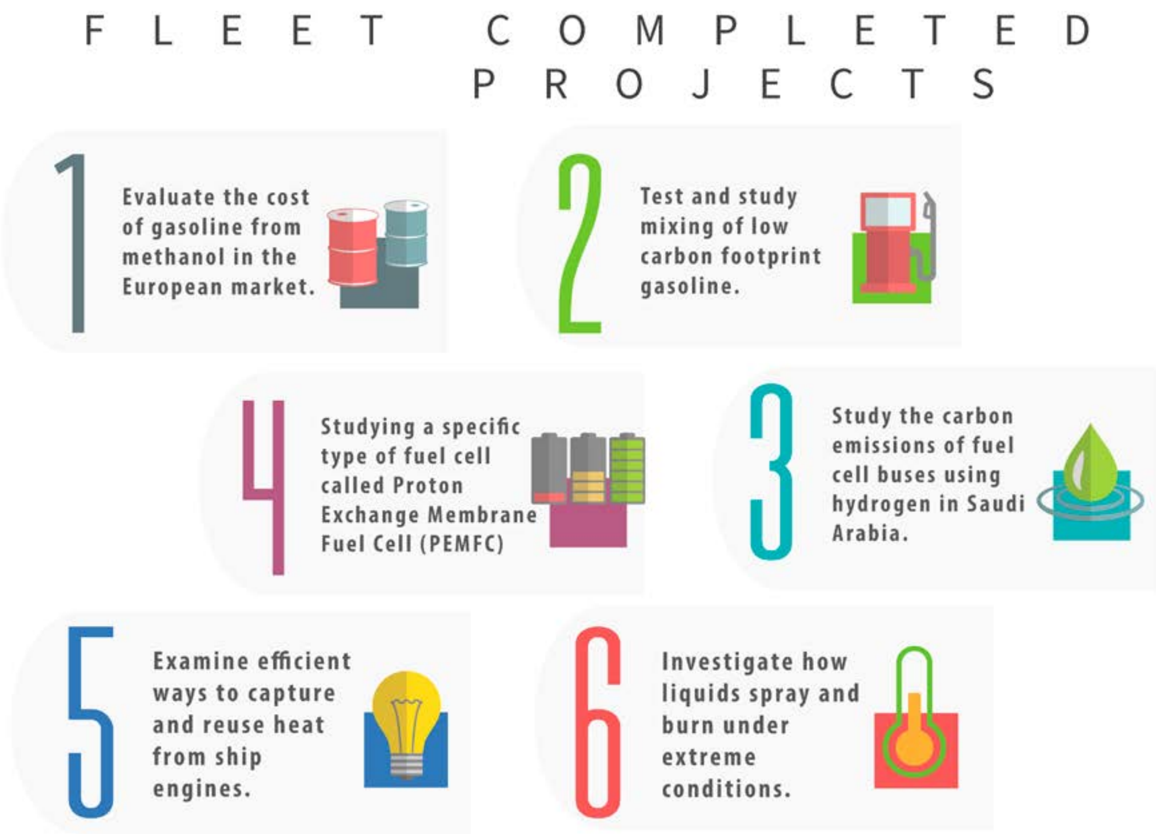
View video

Last year, KAUST and the Oil Sustainability Program (OSP) established the Fuel Lubricants Efficient Engine Technology (FLEET) Consortium with major Saudi and foreign companies, including Aramco, Bahri, Pacific Green Technologies, SAPTCO, Toyota, and Hyundai. This year FLEET welcomed two more companies to the consortium, Luberef and Ferrari.

Founded to enhance fuel and engine design for higher sustainability and economic competitiveness of the transport sector, in just one year, FLEET has completed half a dozen projects. Among them are the study of how liquids spray and burn under extreme conditions, developing new types of fuel cells, and methods to capture and reuse energy released from ship engines.

Following this success, FLEET then announced eight new projects, including ones that attracted the new members. One is the exploration of lubricants in electric and hydrogen-powered vehicles, which reflects the expertise brought by Luberef, and another is new techniques to improve the performance of hydrogen engines, an interest of Ferrari.

FLEET is one of the many recent initiatives taken by Saudi Arabia to achieve a carbon-neutral economy. OSP itself was founded in 2020 and represents multiple government entities,



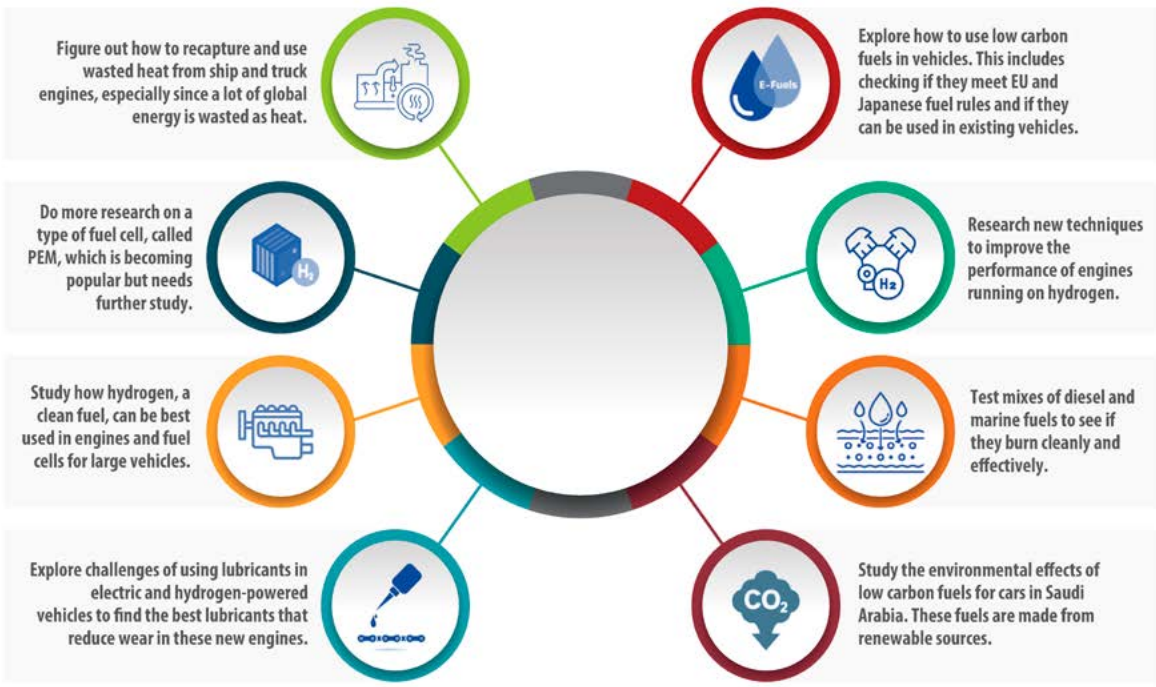
KAUST President Tony Chan welcomes members to FLEET 2.0 at September's launch.

research institutions, and private companies who aim to maximize the added value of hydrocarbons both domestically and globally.

FLEET continues to strengthen the network of government, academic and industry and is already translating research into renewable e-fuels and public transit running with hydrogen fuel cells.

"From evaluating the feasibility of methanol-to-gasoline production and utilization in Europe, to experimenting with fuel blends and running a case study in Saudi Arabia using hydrogen-fueled buses, it's been a busy year for us," said CCRC's Prof. Mani Sarathy, who founded FLEET with Prof. Aamir Farooq.

NEW PROJECTS



Cooperation to fuel change

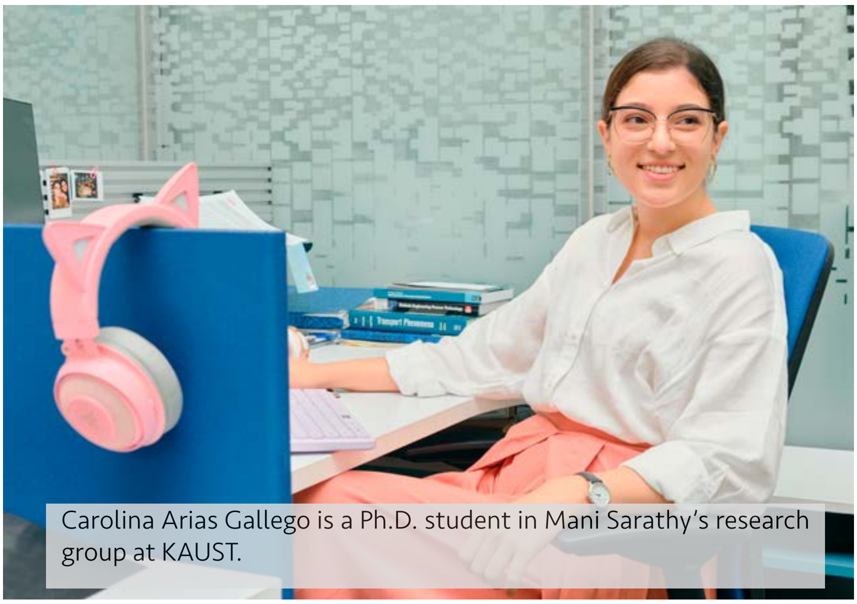
Existing petrochemical refinery infrastructure could be repurposed to manufacture clean e-fuels derived from hydrogen and captured carbon dioxide.

The finding is one outcome from a suite of projects undertaken by the FLEET consortium, a multipartner collaborative research program initiated by KAUST and the Oil Sustainability Program of the Ministry of Energy of Saudi Arabia to reduce the transportation sector's carbon footprint.

"Industrial partnerships are a proven route for translating academic research into real-world applications," says KAUST mechanical engineer Aamir Farooq. But some societal challenges are so great that something bigger than a one-to-one collaboration is required.

"The problem of CO2 emissions from transportation, and the overall sustainability of the transport system, is such a broad challenge that it requires a big team effort to tackle it," Farooq says. "We envisioned the FLEET consortium to bring together multiple stakeholders and companies to work on topics of common interest for this pressing global problem."

Industry buy-in for the concept has been strong, with Toyota, Hyundai Motor Group and Saudi Aramco among the six companies joining FLEET for its 2022 inaugural year. Two more companies, Ferrari and Luberef, joined for 2023.



Carolina Arias Gallego is a Ph.D. student in Mani Sarathy's research group at KAUST.

Productive partnership

The FLEET project was initiated in 2021, when Farooq and KAUST chemical engineer Mani Sarathy proposed the "big team" concept to the Oil Sustainability Program of the Ministry of Energy. "The Ministry folks connected us with various companies, and most companies we reached out to were thrilled by the idea," Farooq says.

Photos: ©KAUST 2023; Eliza Mkhitaryan, Original article from KAUST Insite


From left: Prof. Mani Sarathy, technical and commercial consultant from Luberef Khurram Nadeem and Prof. Aamir Farooq at the FLEET 2.0 launch event.

Each FLEET project is selected in close collaboration with member companies. "An important aspect of the FLEET framework was that the work should not only stay at the university, but should be transferred to the company sites for further testing and prototyping to reach a higher level of technology readiness," Farooq says.

One topic that sparked significant interest was e-fuels. "In the first year, Hyundai, Toyota, Aramco and the Saudi Public Transport Company SAPTCO showed really strong interest in this important topic," Farooq says. The group identified a need for two separate e-fuel projects to be launched.

One, led by Sarathy, explored the practicalities of industrial scale methanol-to-gasoline production. Methanol-to-gasoline is a catalytic process that can produce e-gasoline from green methanol made from captured CO2.

"We wanted to investigate whether we could repurpose refinery equipment for methanol-to-gasoline to reduce the capital and operational cost of the process and make it more feasible for industry," says Carolina Arias Gallego, a Ph.D. student in Sarathy's group.

The team showed that a reactor called a catalytic reformer could be repurposed for methanol-to-gasoline production and calculated that the gasoline price would increase by around US$1/kg when produced by this method. "Considering the minimal price increase and the ability to repurpose existing equipment, the overall cost for industrial application is relatively low," Arias Gallego says.

Proactive participation

A second e-fuels project, led by Farooq, examined e-gasoline utilization. "We've heard a lot about different e-fuels, but there hadn't been a systematic study of the use of these fuels for transportation, from fundamental research to testing in engines," he says.

Due to their different origins and modes of manufacture, e-gasoline and conventional gasoline have key chemical differences affecting their combustion performance. The KAUST team showed e-gasoline's ignition behavior was faster than what is needed in high-efficiency engines but could be modified by blending it with additives ranging from green methanol to conventional gasoline. "The idea to blend e-gasoline with conventional gasoline came from the participating car companies," Farooq says. "They suggested that in the near future we will not have enough e-gasoline to use it alone, so there could be a scenario where blend e-gasoline with conventional gasoline."

Fuel blend samples were sent to Saudi Aramco to run in their test engine, and the next step will be to run them in a real car. "Hyundai has offered to provide the car for vehicle testing," Farooq says.

The FLEET consortium's big team model has been more successful than initially hoped, Farooq says. "I especially enjoy the monthly progress meetings," he says. "Our industrial partners have been very engaged, giving feedback and always looking at ways to take the work forward. FLEET's multipartner consortium model has gained a lot of interest in Saudi Arabia," Farooq notes, and it is being explored for other areas of research, from low-carbon cement production, to composite materials development. "The model works very well and I think we will see it being applied to other grand challenges," Farooq says.

Results through boundary breaking research

Photo: ©KAUST 2023; Anastasia Serin, Original article from KAUST Insite

Leaving the comfortable confines of one academic discipline to apply expertise to an adjacent area of research can deliver high-impact science. That is the path being pursued by Xu Lu, a mechanical engineer who joined KAUST's Clean Combustion Research Centre in 2021.

Lu aims to apply his engineer's outlook to chemistry research questions and is already producing interesting results.

"My research is about electrochemical CO2 reduction, which means we use electricity to convert CO2 into useful fuels," Lu says. "The electricity can come from renewables, and the fuels produced are typically methanol, ethanol, ethylene or formic acid," he says.

Lu embarked on this interdisciplinary research path after branching out from mechanical engineering to join a chemistry department for his postdoctoral training. "By working closely with chemists, I could understand some of the research challenges they face, and where we as engineers might help to solve them," Lu says.

Addressing the issue of carbon emissions by capturing CO2 and recycling it into useful products is a hot topic of research. Most electrochemical research on the subject has studied CO2 recycling at ambient pressure. "But in industry, high-purity sources of CO2 are usually under high pressure," Lu says. "We have tried to take a very practical approach, by studying CO2 electroreduction at high pressure."

Engineering expertise is very helpful for running the large and complex high-pressure reactors the team use to conduct CO2 electroreduction at 50 bars of pressure. But it is a multidisciplinary research effort, Lu adds. "My research group includes engineers, system engineers, material scientists and chemists, all working very closely together," he says.

The team's results show how stepping out of your research comfort zone can really pay off, Lu argues. "The high-pressure set-up gave us a surprising result," he says. Usually, CO2 electroreduction generates a mixture of formic acid, methanol, ethanol and other products. "But under pressure, the reaction becomes highly selective for formic acid production, which is much more useful than a mixture," Lu says. "Now we are trying to convert the high-pressure CO2 into other single products," he adds.

Joining KAUST proved to be an excellent move for conducting cross-disciplinary research with scientists from other fields, Lu says. "Before I came to KAUST, the resources here attracted me, and I was able ramp up my lab very quickly. After I arrived at KAUST, I realized that it is a great place because we are supported to work with colleagues, without boundaries."

Lu's work includes collaborative projects with KAUST Solar Center researchers. "I'm doing electrochemistry, which means you need electricity, and of course it should be from solar," he says. One project with material scientist Stefaan De Wolf, for example, explores connecting chemical electrolysers to solar cells without the need for batteries.

"I tell my students and postdocs, if you look at the world of industry, everything is already cross connected – chemistry with engineering, medicine with biology and AI with everything," Lu says. "If you stick to your own little research field you will never make something impactful. To achieve something amazing, you have to leave your comfort zone."

CNN visits CCRC

This summer Prof William Roberts and team were visited by CNN to feature an ongoing project that aims to achieve greener shipping fuels.

Scan to watch video

Providing tech support to King Saud University

Earnesto Thachil (left) and Dr Idris Bedja (right) working on the laser.

With the scarcity of skilled laser technicians, Earnesto Thachil, a laser technician at the CCRC, found himself travelling to King Saud University to assist Dr. Idris Bedja in resolving an issue with an Nd-YAG laser (Surelite II -10) from Amplitude Lasers, which is an integral component of a transient absorption spectrometer setup.

Dr. Bedja, an associate professor in the Department of Optometry at King Saud University, was experiencing difficulties with the laser's performance, which hindered his research activities. Recognizing the critical role of the laser in Dr. Bedja's research, CCRC readily agreed to provide technical support by sending Thachil to spend several days at King Saud University to address the laser's malfunction. His expertise and dedication proved invaluable in resolving the issue and enabling Dr. Bedja to resume his research.

Thachil's willingness to travel to King Saud University and provide hands-on technical support exemplifies CCRC's commitment to fostering collaboration and supporting scientific research across institutions. His efforts not only addressed an immediate technical challenge but also strengthened the ties between CCRC and King Saud University.

FUELCOM4 kick-off meeting ignites hydrogen fuel innovation

CCRC recently hosted the kick-off meeting for FUELCOM 4, a 14-year industry-academic collaboration with the Transport Technologies Division at Saudi Aramco's Research and Development Center. This partnership has a proven track record of success, exceeding expectations in terms of both outcomes and talent development.

FUELCOM aims to develop early-stage technology through the science and application of core ideas that underpin Aramco's current transport R&D program. Specifically, FUELCOM has served as a lever for two of Aramco's research pillars: increasing the efficiency of internal combustion engines and the use of low climate-impact fuels. This work supports the decarbonization and sustainability of the road and marine transport sectors.

FUELCOM has evolved over time, transitioning from a fundamental and curiosity-driven approach to more translational-driven projects. Now in its fourth phase, FUELCOM 4, a 3-year endeavor, focuses on the highly important area of hydrogen fuel. The project aims to demonstrate the feasibility of hydrogen as a fuel for real-world vehicles. A key challenge is determining how to effectively utilize hydrogen in combustion engines. FUELCOM 4 researchers believe that retrofitting existing engines is a more economically viable solution than designing and building new ones. This approach aligns with FUELCOM's overarching goal of sustainability.

Each phase of FUELCOM begins with a collaborative discussion and exchange of ideas to identify specific project goals. These discussions eventually lead to a 'statement of work', which in the case of FUELCOM 4 has resulted in six work packages focused on hydrogen utilization in internal combustion engines. This project is characterized by its highly multidisciplinary nature, with contributions from several co-principal investigators (co-PIs). Professor Aamir Farooq serves as the project lead.

FUELCOM 4 is an exciting initiative with the potential to make a significant contribution to the development of hydrogen fuel technology.

Prof. James Turner participated on a panel to discuss new technologies and alternative fuels for shipping at the Sustainable Maritime Industry Conference (SMIC) in Jeddah.

The goal of SMIC was to find new and innovative ways to reduce the environmental impact of the maritime industry while maintaining economic viability for this sector.

The 13th annual meeting of the Saudi Arabian Section of Combustion Institute (SAS-CI) was hosted at KAUST in October.

The meeting's theme, "Towards a Sustainable Energy Future" brought experts from government, industry and institutions in Saudi Arabia, Belgium, Austrailia, UK and the US together. At the meeting topics ranged from ai in combustion, the role of combustion in decarbonizing heavy industry, and sustainable fuels for future mobility.

At the KAUST New Energy Oasis, Prof Farooq and his team achieved validation for their methane leak detection laser sensor in a real-world environment.

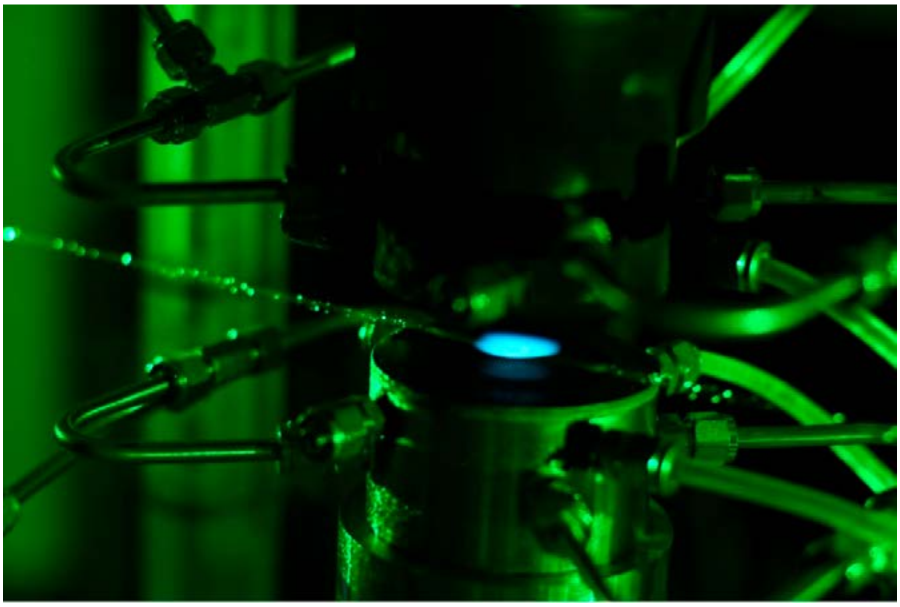
The project garnered the presence of collaborators from Aramco, including members from the Upstream Research Center, Upstream Business Support Department (UBSD), and KAUST EXPEC Advanced Research Center. This versatile laser sensor demonstrates its capability to detect leaks in various applications, ranging from power plants to methane production.

In October CCRC participated in MENA Climate Week. Prof Bill Roberts contributed to a panel discussion with leaders from Saudi Electric Company, General Electric, Acwa Power and Alfanar. Roberts emphasized the critical role universities like KAUST can plan in enabling the decarbonization of the power sector.

Dr. Sai Sreedharan and Dr. Deoras Prabhudharwadkar participated in a discussion on the KAUST/Saudi Electric Company partnership for the depolyment of the Cryogenic Carbon Dioxide and Other Pollutants Capture technology at Rabigh and Green Duba power plants.

The Green Duba Cryogenic Carbon Capture project is one of two inaugural projects in the newly announced KAUST National Transformation Institute.

Freeze charges in flames



A burning flame is full of charged particles that can be affected by an electric field. KAUST researchers have now studied the use of high voltages to control these particles, which could potentially reduce soot formation and improve a flame's stability[1].

"Although there is no application yet, we believe that this scientific knowledge will fuel the areas of fire extinction, air and space propulsion, and even using flames in space," says Min Suk Cha, who led the research team.

Scientists already knew that burning fuels generates electrons and ions. In recent years, the KAUST team has shown that electric fields cause these ions to flow as an "ionic wind," which can affect the shape of the flame and the combustion process.

To better understand this phenomenon, the team developed a simulation to show how the electric field shapes the ionic wind. "Ultimately, we want to establish a comprehensive predictive tool," says team member Jinwoo Son. The simulation included numerous factors, including the strength of the electric field, the different types of ions in the flame and their distribution.

"Potential areas include optimizing heat transfer in an efficient industrial furnace, microthrust and propulsion, fire extinction, and space utilization."

The researchers tested these predictions by studying a flame inside a cavity exposed to electric fields of up to 2,500 volts. Methane gas entered from one side of the cavity, while oxygen entered from the opposite side, creating a band of flame in the middle. The team measured the electric field at different points in the flame using high-power laser pulses, a method called Electric Field Induced Second Harmonic generation (EFISH). The researchers modified the EFISH technique to include a switch that could turn off the voltage in just one hundred billionths of a second. This effectively freezes the flame's ions in time and space, so that EFISH could take an accurate snapshot of their distribution.

The experimental results largely agreed with the simulation, but there was a notable discrepancy in the local electric field close to the fuel outlet. "In that region, the experiment showed an increase in the electric field, whereas the simulation showed little change in the electric field," says team member Jin Park.

This heightened electric field was caused by negatively charged ions of partially burned fuel, which were unexpected and had not been included in the simulation. The researchers suggest that further measurements of negatively charged ions derived from fuel molecules should feed into future simulations to improve their accuracy.

"I believe that our scientific quest in this area is coming to an end soon," says Cha. "Our next step will be applying our knowledge to a practical application. Potential areas include optimizing heat transfer in an efficient industrial furnace, microthrust and propulsion, fire extinction and space utilization."

Article by: **Jin Park & Jinwoo Son**. Ph.D. student & Postdoc

Reference: Park, J., Son, J., Butterworth, T.D. & Cha, M.S. Electric fields in a counterflow nonpremixed flame: measurement and simulation. Scientific Reports 13, 7622 (2023).| article

Advancements in Waste Heat Recovery Cycles for Heavy-Duty Vehicles

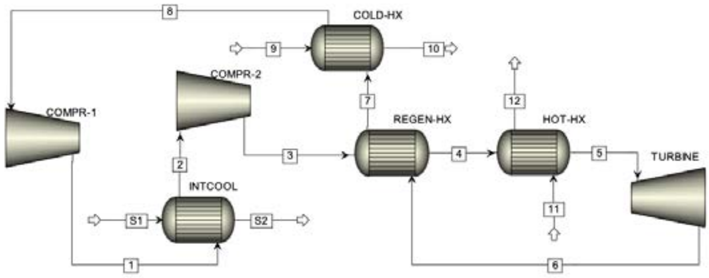


Fig. 1: Schematic of the closed Joule cycle (CJC) with intra-cycle heat regeneration and intercooling used in this study [2].

In the global pursuit of energy efficiency to combat fossil CO2 emissions and address climate change, waste heat recovery (WHR) systems take center stage, particularly in internal combustion engines (ICEs).

With the imperative to enhance efficiency, whether using fossil or renewable energy, the focus is on reducing energy consumption and subsequent CO2 emissions. The potential of ideal e-fuels, crafted from renewable sources, is acknowledged, but high capital costs necessitate a parallel emphasis on energy utilization efficiency.

Internal combustion engines, notorious for wasting fuel energy as heat, present a prime target for WHR systems. Mechanical turbocompounding and electrical turbocompounding have been explored by other researchers, and they showcased their roles in extracting excess thermal energy. Positive-displacement mechanical turbocompounding, exemplified by experiments using the Wankel engine, has been considered for its efficiency in waste energy recovery. Another WHR concept extensively explored in other research uses the Organic Rankine Cycle, which requires significant space on a transportation platform. A novel concept that was less explored was using Joule cycle-based WHR, such as the Inverted Joule Cycle, and the Closed Joule Cycle, particularly with regard to heavy-duty (HD) trucks and marine engines.

KAUST researchers have made significant strides in developing simulation models based on Closed Joule Cycles and Open Joule Cycles (CJCs and OJCs). Real-world drive cycle data of a 40-tonne Scania truck taken from Rijpkema et al. [1] was used to test the developed models. The CJC studied, fitted with intra-cycle heat regeneration and intercooling, is shown in Figure 1 and emerges as an optimal initial choice, finding a delicate balance between practicality, efficiency, and specific work output based on their earlier work. The investigation dived deep into the nuances of cycle layout, working fluids such as argon, air and CO2, and the overall pressure ratio, while maintaining a constant lower cycle temperature of 30°C and allowing for variable upper cycle temperatures [2].

In the pursuit of simplicity, the authors extended their exploration to the OJC. With heat regeneration and intercooling, this cycle benefits from a noteworthy 10°C reduction in lower cycle temperature (important due to the relativelu low upper cycle temperature in most heat recovery schemes), and essential resembles an open gas turbine with indirect heat addition.

Results suggest a useful increase in overall engine system efficiency in truck applications, ranging from 2.4-2.6% for the CJC and up to an impressive 4.1% for the OJC [2]. Comparative analyses with existing Organic Rankine Cycle studies underscore the promise of Joule cycle-based WHR systems. While exhibiting slightly lower efficiency, the latter systems offer the distinct advantages of simpler equipment and a more practical working fluid since air can be used.

The research, while recognizing certain limitations and advocating for more comprehensive modelling, positions Joule cycle-based WHR as potentially a transformative avenue for enhancing powertrain-level efficiency in heavy-duty applications. With potential benefits quantified, the study provides a compelling case for further exploration and potential implementation in sectors operating engines at high loads and for extended durations.

Technical Update by: **Sreenivasa Rao Gubba,** Application Specialist, **Kesty Y. Kenkoh** Ph.D. student, and **Prof. James W. G. Turner**

Capturing clean energy from tropical seas

Prof. Bassam Dally

Photos: ©KAUST 2023; Morgan Bennett Smith & Anastasia Serin, Original article from KAUST Insite

Not all sources of renewable energy are intermittent. A continual flow of clean power could be provided by a technology that harnesses the temperature difference between the sea's surface and deeper waters to generate electricity. The technology could be suited to powering small Red Sea island communities, as calculated by Bassam Dally, a thermo-fluid scientist from KAUST.

Dally came upon the ocean thermal energy conversion (OTEC) concept while exploring alternative potential clean energy sources, he explains. "We were looking at the challenges of storing energy from intermittent renewables such as wind and solar when we realized that we need to broaden our focus," Dally says. He began to explore energy sources that deliver renewable power more consistently.

Since joining KAUST in early 2021, Dally has investigated the potential for using OTEC technology in the Red Sea. "Surface water temperatures here can get up to 30 or 35 degrees Celsius during summer," he says. Just 200 meters below the surface, the temperature falls to around 21 degrees Celsius. "Thermodynamics tells us that, once you have a temperature gradient, you have an energy potential you can do something with," he says.
OTEC exploits this gradient in a process called an organic Rankine cycle. The hot water is pressurized, then the pressure is immediately released, vaporizing it. The vapor drives a turbine to generate electricity, before being condensed by the cold water to complete the cycle. The power produced is relatively modest; a full-scale

unit might power several hundred homes, Dally estimates.

"But you gain continuous clean energy from a device with a small footprint and very little maintenance requirement," he says.

OTEC has typically been trialed in areas where deep ocean water as cold as 4 degrees Celsius can be accessed, increasing the temperature differential and the power-generating efficiency of the cycle.

For the Red Sea setting, Dally has run calculations on two possible OTEC enhancements. "We looked at optimizing the cycle by trying to recover some kinetic energy from the discharged fluids," he says. "We also looked at coupling OTEC with a source of waste heat." To compensate for the lack of very cold water, Dally explored boosting the hot side using waste heat from various thermal facilities.

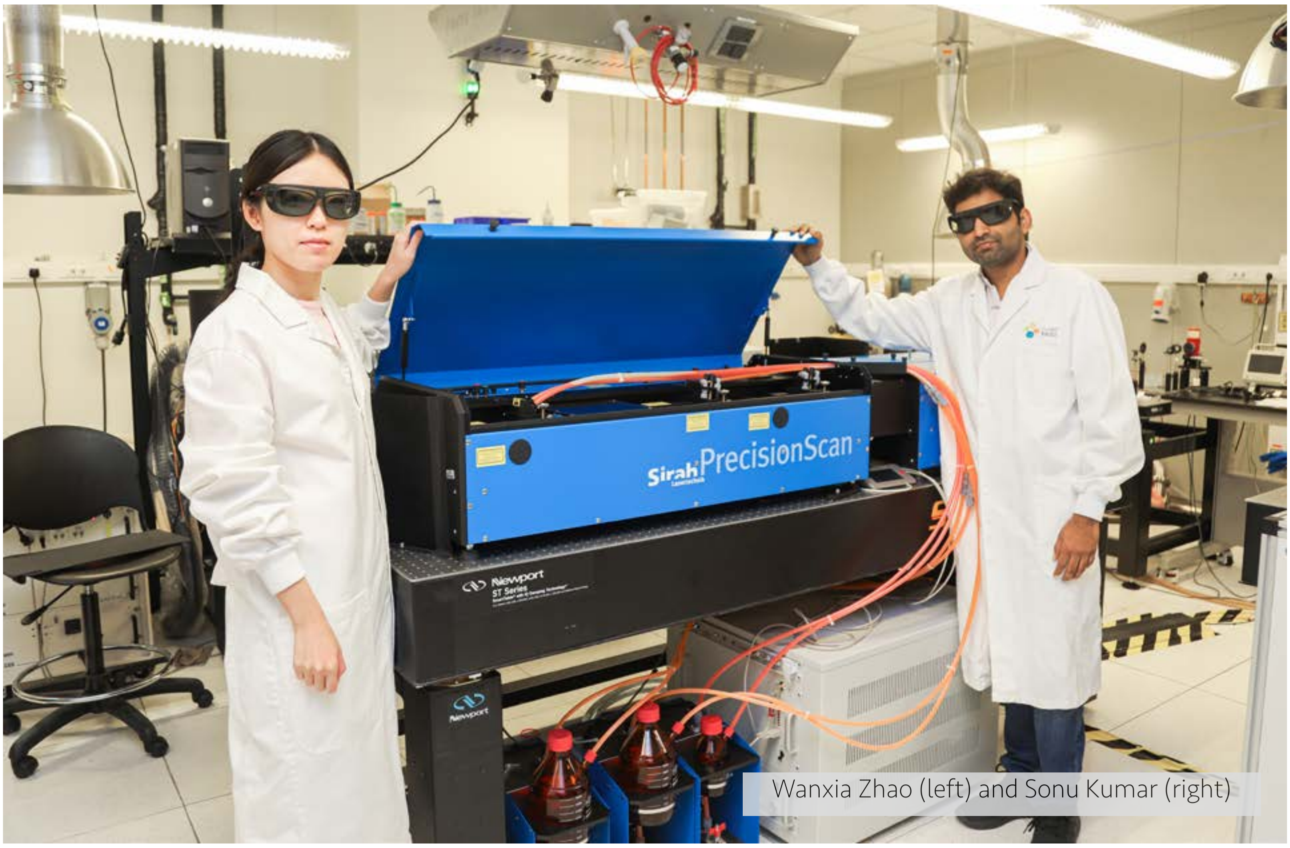
Dally found that using waste heat would reduce the OTEC levelized cost of electricity significantly. For island communities such as those planned for NEOM, this work suggests that the technology could be a better option than shipping in diesel to power generators, running electricity cables from the mainland or installing large arrays of solar panels and batteries.

"For island communities such as those planned for NEOM, this work suggests that the technology could be a better option."

"For niche markets such as small island communities in ecologically or environmentally sensitive areas, it could make a lot of sense to generate electricity this way," Dally says.

"Discussions with potential investors to fund a pilot of the technology in the Red Sea are now underway," he adds.

Temperature measurement in high pressure sooting flames



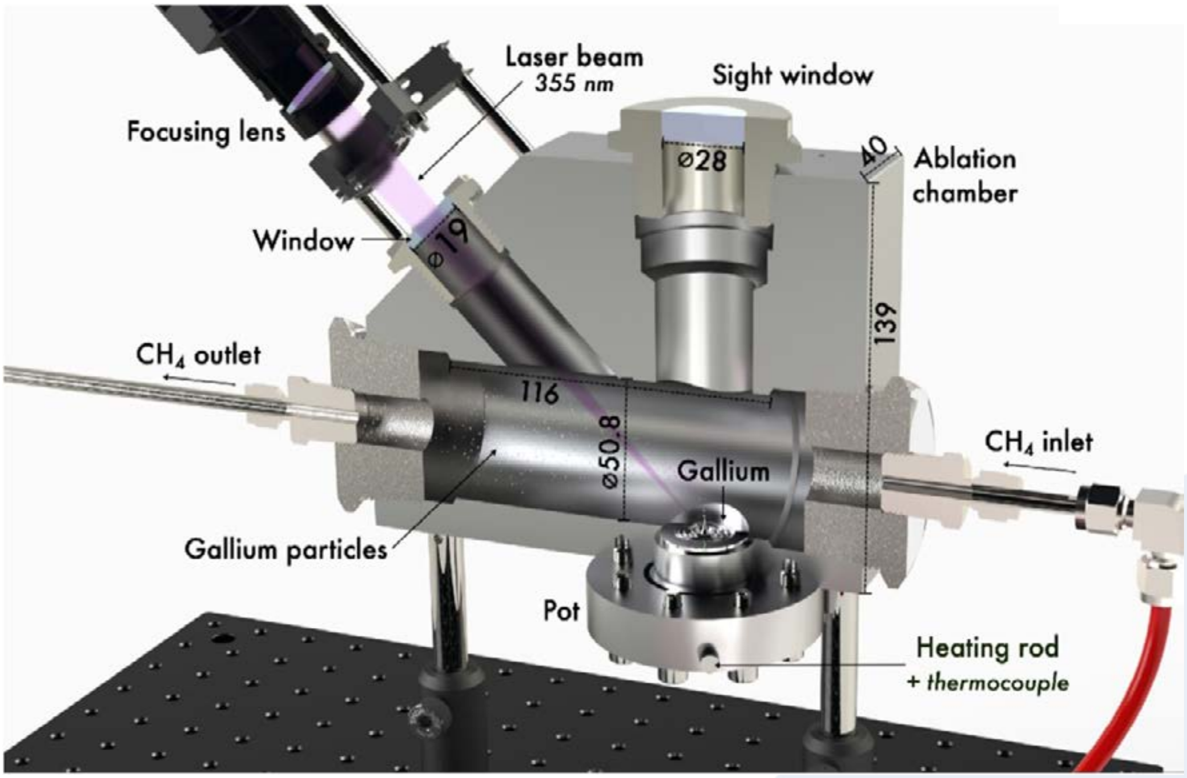
Wanxia Zhao (left) and Sonu Kumar (right)

Researchers led by Prof Bassam Dally and Thibault Guiberti have adapted the planar Two Line Atomic Fluorescence, TLAF, technique to accurately measure the gas temperature of sooting flames under high pressure.

The team has developed a new liquid-based ablator to seed gallium nano-particles into the flame and monitor the emission at two wavelengths in the UV.

TLAF involves the excitation of two electronic transition states to the same upper state, providing fluorescence signals that exhibit good signal-to-noise ratios and low spectral interference from native species in the flame when compared with any other non-intrusive techniques. The temperature is determined through calibration in the non-linear regime, using a reference flame. TLAF is not affected by molecular collisions, and various metals were suggested as tracers, including gallium, thallium, and indium. Gallium is chosen in this study because of its strong signal over a wide range of temperatures 300 K - 2600 K.

The new technique was demonstrated in the center's HPCD facility under laminar, turbulent, sooting conditions and different pressures. It was found that the signal remained strong up to 6 bars and that gallium was an effective tracer at levels of hundreds of PPM. The low concentration of the tracers guarantees a very minimal impact on the flame structure. The results were compared with Rayleigh-based measurements in soot-free laminar flames and found to agree very well. The new seeder and measurements show a clear advantage of gallium-based TLAF over traditional thermometry techniques such



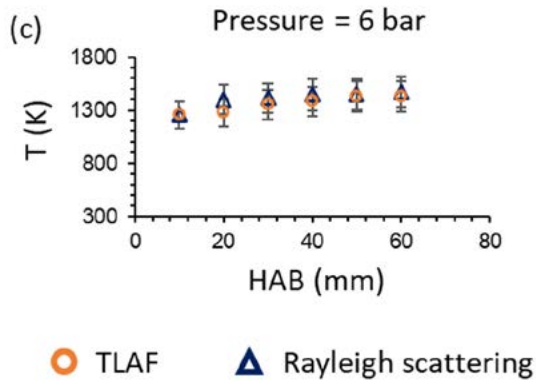
Newly developed ablator to generate gallium nanoparticles

as Rayleigh scattering, spontaneous Raman spectroscopy, 2D coherent anti-Stokes Raman spectroscopy, and Laser-induced fluorescence (LIF) of flame-generated species.

These other techniques are most effective in particle-free, or at very low particle-loading flames as they suffer strong interference from the presence of particles in the flames. Additionally, these techniques rely on the fluorescence of species (e.g. OH, NO, CH) to be present in the flame during the combustion process, which might be present in a thin reaction zone or insufficiently concentrated to give a good signal-to-noise ratio, particularly in heavy sooting flames.

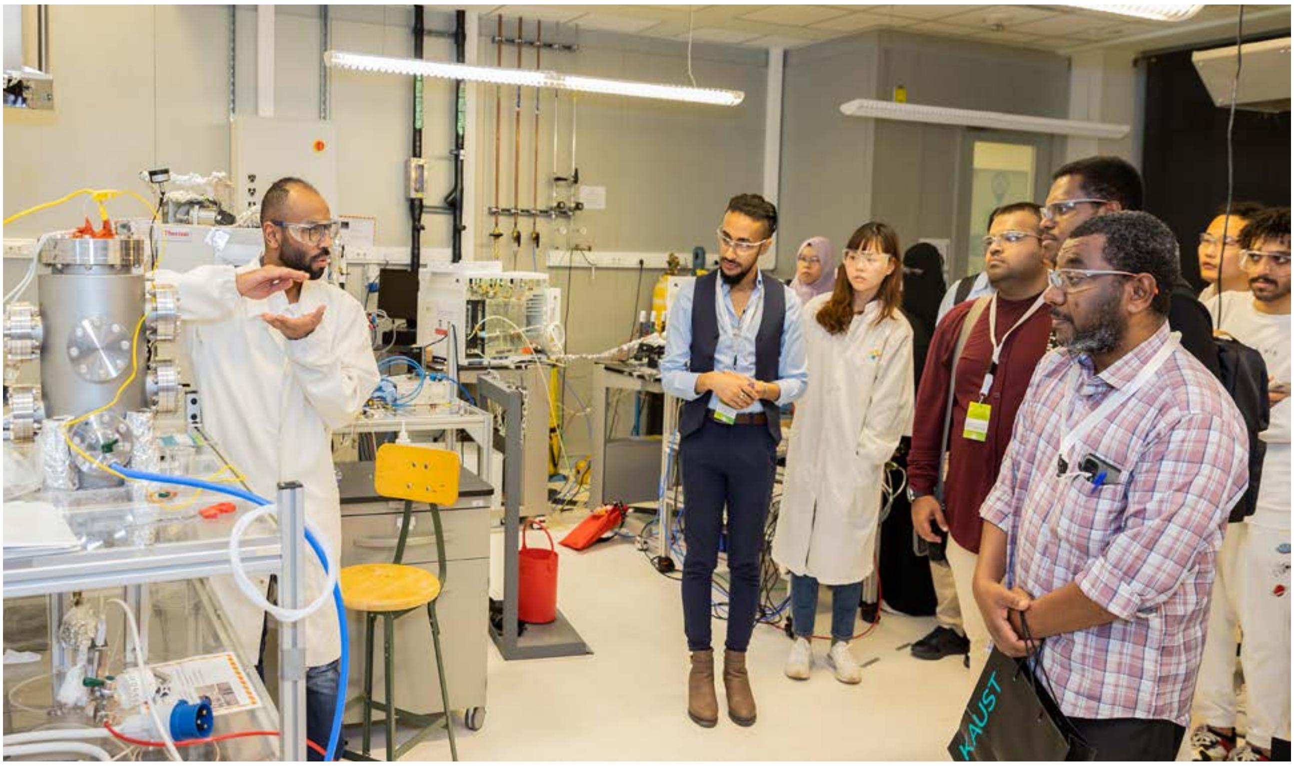
"The gallium-based TLAF thermometry technique will now be applied to multiple reacting flows involving, soot, metal particulates, spray, and high pressure", says Prof Dally.

Update by **Wanxia Zhao** Postdoc, and **Sonu Kumar** Postdoc, with **Prof. Bassam Dally** and **Thibault Guiberti**



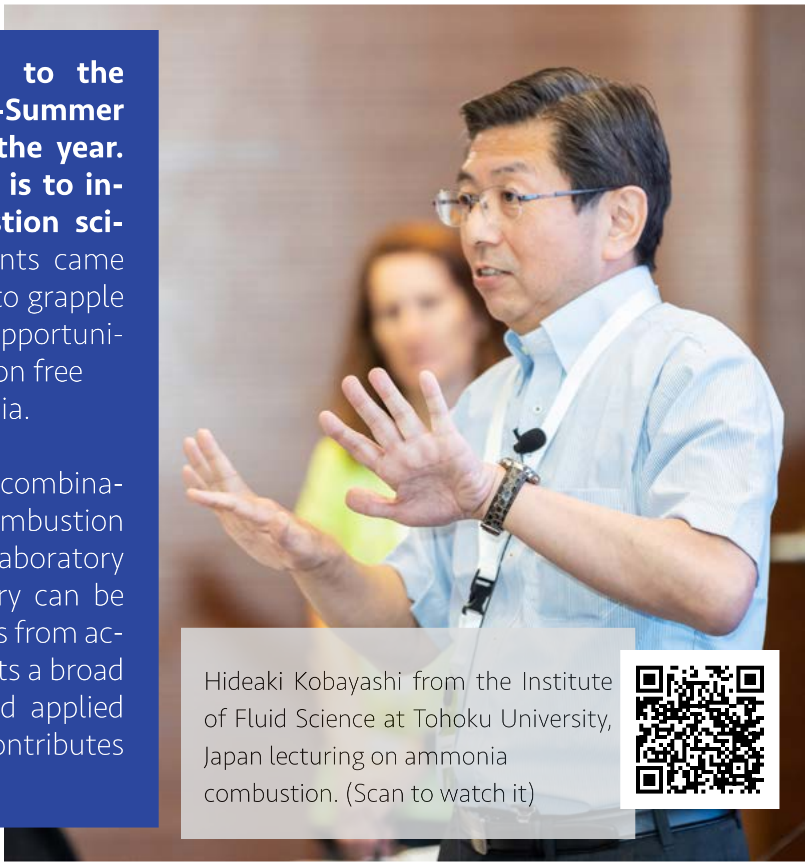
Comparison between TLAF and Rayleigh Scattering

KAUST CI-Summer School:
How can we build a sustainable world?



CCRC welcomed students to the Combustion Institute-Summer School (CI-SS) earlier in the year. The goal of the summer school is to increase the visibility of combustion science to young scientists. Students came mostly from Saudi Arabia and got to grapple with critical topics including the opportunities and challenges of burning carbon free fuels such as hydrogen and ammonia.

The school was delivered using a combination of lectures on fundamental combustion science together with practical laboratory sessions demonstrating how theory can be applied. Instructors included experts from academia and industry, giving students a broad understanding of fundamental and applied combustion science, and how it contributes to a sustainable future.



Hideaki Kobayashi from the Institute of Fluid Science at Tohoku University, Japan lecturing on ammonia combustion. (Scan to watch it)

KAUST's Got Talent top prize winners from CCRC

Ph.D student Michael Oyinloye and Research Scientist Giovanni Vorraro, both from the CCRC, bagged the top prize in the KAUST's Got Talent show during the summer.

The pair's captivating performance wowed the audience - a testament to the diverse talents that lie within the community and our center.

Michael's research focuses on Cryogenic Carbon Capture, Desublimation, and Fluid-flow Modeling while Giovanni's focus is Hybrid Electric Vehicles, Internal Combustion Engines, e-Fuels, Fuel Cells, Numerical Modelling, and Experimental Activities.

Meet Kevin Nall
CCRC's Strategic Business Development Officer

Kevin Nall is no stranger to KAUST. Before joining CCRC in December 2022, he managed an executive leadership program in higher education as well as professional development programs for emerging leaders in business and law for Strategic National Advancement (SNA) for four years.

What made you return to Saudi and KAUST?

I came back to KSA because of the enormous growth and opportunity taking place at KAUST and in the Kingdom. It's an opportunity to get in on the ground floor of something very big that is happening. So much has changed just since I first arrived in 2018. The Kingdom's bold Vision 2030 has unified every sector and the people of Saudi Arabia are proud to be a part of that Vision

Why did you join the Center?

I joined CCRC for 3 reasons.

1. Because of the center's drive to commercialize and deploy its research to make a difference in people's daily lives. Right now, most of it is directed at sustainability and CO2 reduction efforts. Our faculty are providing real-world solutions in pre-combustion, combustion, and post-combustion efforts.

2. Because there are incredibly talented and motivated students. They approach their research from a place of passion. It's been said that "if you truly love what you do, you'll never work another day in your life" and to me, these students and researchers are the embodiment of that sentiment.

3. I joined CCRC because of Professor Bill Roberts. One of my first experiences with CCRC was on a Thursday. Looking around the building, I noticed that everyone was wearing some variation of a Hawaiian or tropical-themed shirt. Turns out they celebrate "Tropical Thursdays". Almost everyone from students, postdocs, researchers, staff, and faculty participates. I was impressed when I saw Professor Roberts wearing his Tropical Thursday shirt as well.

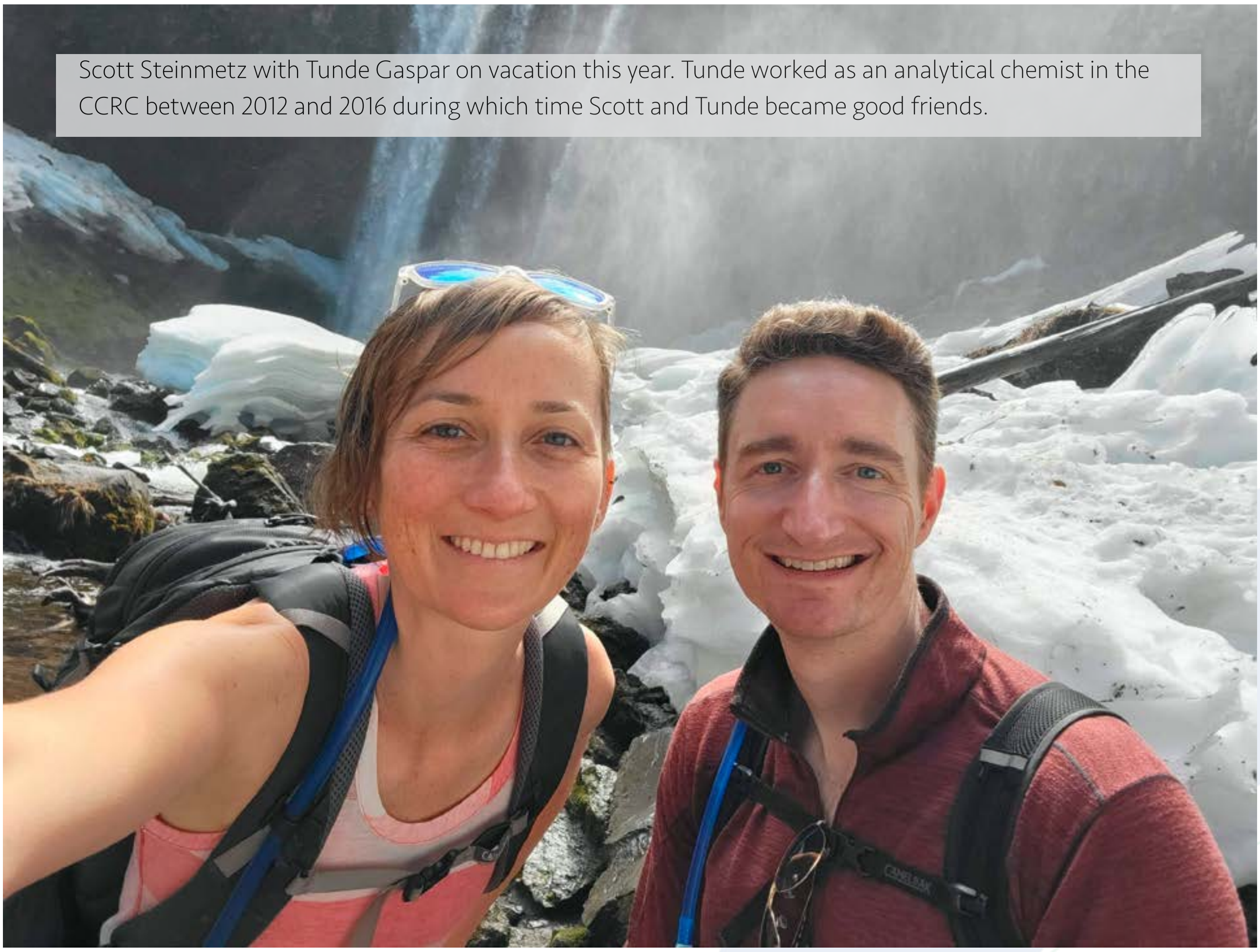
Roberts hires talented people and gives them the freedom to do what they do best. It is probably the most motivated office I have ever worked in. That message must be created/directed and modeled from the top and delivered to every level. And it must be genuine. Professor Roberts leads from the front and as a result, the Center flourishes, and functions at a very high level.

Tell us more about your work in CCRC?

Essentially I connect our faculty and their research interests with industry partners who are interested in the same things. I have two great colleagues, Sree Gubba and Leiliang Kobayashi. We are responsible for working with the CCRC Industrial Advisory Board. A group of eleven government and industry executives who meet with us twice a year. We also support faculty in other ways like funding proposal generation, providing conference speakers from our industry contacts, and providing project management with them for projects once they are funded.

When hosting them industry parnters at KAUST I always enjoy seeing how amazed they are by the facilities and equipment we have here. Ultimately, we are asking them to partner with us financially and it's important that they trust us and our ability to deliver what we say we will. But sit in on a meeting with any of our faculty and potential industry partners and very quickly you realize that we have a lot to offer. The questions our faculty ask often take the industry guys by surprise with their level of depth and knowledge of how well they understand industry.

Make no mistake, KAUST is in the arena. CCRC is in the arena and it's just a momentous time to be here and have the opportunity to contribute.



Scott Steinmetz with Tunde Gaspar on vacation this year. Tunde worked as an analytical chemist in the CCRC between 2012 and 2016 during which time Scott and Tunde became good friends.

Scott Steinmetz

PhD 2016
Program: Mechanical Engineering
PI: Prof. William Roberts
Current Position: Research Scientist, Lawrence Livermore National Laboratory, USA

I joined KAUST at a very exciting time, when it was still in its early stages and the CCRC labs hadn't been fully commissioned. Though there were some growing pains, this provided a unique experience as I grew as a researcher while the CCRC grew as a world-renowned institution.

The advising of Prof. Roberts and the help of the other professors, scientists, and fellow students in the CCRC allowed me to develop the skills to become an independent researcher.

During my time at KAUST, I met many amazing people from all over the world, and formed friendships that continue to this day. I think that kind of international experience is important to grow as a scientist and as a person.

My PhD experience solidified my desire to continue as a researcher in an academic or national lab setting, where I can continue to make scholarly contributions. The connections I formed at KAUST and at international conferences, as well as the excellent reputation of the CCRC led into postdoctoral positions and The University of Sydney and at Sandia National Laboratories, and finally, a staff position at Lawrence Livermore National Laboratory.

As a research scientist, I'm eager to further expand the optical diagnostics skills I first garnered at KAUST, and to develop the leadership and management skills necessary to be a successful principal investigator.

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