

PETROCHEMICALS
AND THE LOWCARBON ECONOMY:
VERSATILE
SOLUTIONS
FOR GREATER
SUSTAINABILITY

REPORT OF THE 52ND EPCA ANNUAL MEETING

VIENNA, AUSTRIA FROM 7th TO 10th October 2018





European Finals of the EUROPEAN YOUTH DEBATING COMPETITION (EYDC) 2018

"Living, learning, working and moving in Smart Cities of the future: with or without plastics and petrochemicals?"

or the third year running, EPCA and PlasticsEurope hosted the European Finals of the European Youth Debating Competition (EYDC) at EPCA's 52nd Annual Meeting on Monday 8th October 2018. In addition to promoting a tangible approach to education in Science, Technology, Engineering and Mathematics (STEM education), the debate series which took place from April until September 2018 in nine countries in Europe aims to encourage young people to explore topics related to the petrochemical and plastics industry, and develop the soft skills linked to presenting, defending, integrating and challenging ideas, that can be used in their future careers, irrespective

of their role and path. As EPCA President and Arkema France's Executive Vice President Marc Schuller noted in his introduction, the competition gives the industry an opportunity to engage with young people, and, hopefully, will help and encourage the participants to become future leaders.

With increasing urbanization worldwide, Marc Schuller underlined the importance of Smart Cities in improving standards of living and in protecting and enhancing the environment. He also noted the role being played by the petrochemical and plastics sector in helping to make Smart Cities a reality with processes and products that enable greater energy

efficiency in homes, offices, and transport and enhanced and connected digitisation. However, Marc Schuller also emphasised the need for public-private collaboration, and for more innovation and a changing culture to make Smart Cities a reality.

Welcoming both participants and audience to the debate, Dominic Weiss, Head of Smart City Agency, Urban Innovation Vienna GmbH said that in pursuit of "being a Smart City, Vienna is offering a local answer to a global problem." He also noted that Vienna is widely recognized as one of the world's most liveable cities, and which focuses on providing every citizen with a high quality of life.

"Petrochemicals will always play a huge role in smart and innovative urban infrastructures of our future. We therefore have to work closely together to find the best solutions"

And while Vienna can offer Smart City examples to other cities, they will necessarily



need to develop different approaches appropriate to their needs, he said. However, Dominic Weiss outlined four challenges which Vienna and other cities need to address: climate change, resource management, globalization and increasing urbanization. "There are 40,000 people per year coming to Vienna," he stated, and rapid population growth is also occurring in other cities.

Two experts were introduced as pro- and con-speaker to kick off the debate. Anne-Gret Iturriaga Abarzua, Head of Communications at INEOS KÖLN GmbH, said there is no question that plastics and petrochemicals are essential to achieving the Smart City. However, she noted the biggest challenge is defining how and where they can best be used. Echoing Marc Schuller, she added that through innovation and technological progress, "smart plastics can provide smart solutions for Smart Cities" and reduce the environmental impacts of future urban living, moving and working. Petrochemicals and plastics provide intelligent solutions for our modern world - now and in the future.

Countering what he called "this utopian view" of plastics in the Smart City, Thomas

Roiss, Student Researcher at the Munich Center for Technology in Society, Technical University Munich (TUM), said society needs to recognize the "dark side" of plastics and chemical waste, and the social and environmental impacts which affect the poor much more than the rich. "I don't advocate a world without plastics. But the keyword is: Responsibility." We need to develop systems to better manage and minimize the negative impacts of these products, which requires regulation and cooperation between producers, suppliers, consumers, governments and citizen groups, he said. "We have to recognize that right now we are not on a sustainable path."

The youth debate was a fierce, hard-fought, closely argued, contest, with "red" and "yellow" cards used for interventions, and bells rung to tell speakers their time was either short or up. Speaking in English, a second language for most participants, and with considerable fluency and confidence before a 11-person jury and a sizeable audience, the 30 young finalists from the nine European countries offered well-structured arguments as to why petrochemicals and plastics should or should not play roles in Smart Cities.

The "Pros" painted a convincing picture of the contribution plastics and petrochemicals are already making and will in future make to the development of Smart Cities and a better standard of living for the increasing numbers of people inhabiting them. They underlined the contributions of plastics in generating renewable energy, and in reducing energy use in buildings and transportation, or in transforming the hardware of mobility and construction. They illustrated the use of plastics in smart technology - from computers, to smart phones and smart appliances - and their contribution in enabling the digital connectivity so essential to Smart Cities, and the transformation of access, delivery and diversity in education.

The role of plastics in food safety, preservation and delivery was highlighted. Benefits plastics deliver to human health were also described: from medical products such as syringes and intravenous delivery tubes to artificial bones, prosthetics and pacemakers, to safe, protective packaging for pharmaceuticals. While acknowledging the waste issue associated with petrochemicals and plastics, the "Pros" claimed the products





themselves were not to blame. Rather, our throw-away culture and lack of waste management and recycling infrastructure are today's challenges. Moreover, technological solutions to these problems are increasingly available and effective.

The "Cons" made forceful arguments against the use of plastics and petrochemicals in Smart Cities. They highlighted the contribution to climate change made by the use of oil and gas, the industry's primary feedstocks. The "Cons" also pointed out the general environmental effect caused by the production, use and disposal of these materials. Surely, to be smart, Smart Cities – and the societies and industries that create, live and work in them - need to find harmless but useful replacements

for these materials, or at least implement effective mitigation technologies before using them. Also, the "Cons" questioned whether the IT technology enabled by the industry's products has really improved education, or simply increased the delivery options and speed while depleting the creativity of children and young people.

Some fundamental challenges were issued by the "Cons" to the petrochemicals and plastics industry. Aren't the producers and processors a huge part of the problem for pursuing growth in volumes, sales and profits while failing to help implement a circular economy? Why aren't more technologies and products being developed that mitigate the industry's negative impacts? Given the immediate-to-long-term

challenges of population growth and climate change, should Smart Cities continue to use finite oil and gas resources for power, building and transportation, or accelerate the use of alternative, renewable resources?

Ultimately, the debate ended in an honourable draw. Smart Cities need petrochemicals and plastics. But they also need smart citizens, smart governments, and smart public and private sectors collaborating to produce, use and reuse or recycle them in smart ways.

To get to the European Finals, over 450 participants aged 15 - 19 took part in nine National Finals in France, Germany, Croatia, Bulgaria, Spain, Italy, Poland and the UK, and a joint Benelux final for Belgium and the Netherlands. Jury members for the European Finals admitted it was difficult to rank participants but chose the following participants in order from 1st to 10th place: Matsuko Sano from France, Huda Daghem from the UK, Giulia Dargenio from Italy, Leon Zrnić from Croatia, Jiawei Zhang from France, Jason Yeager from Belgium, Ana Navarro Bullo from Spain, Adam Roden from France, Joanna Maria Kesicka from Germany and Michael Fox from the UK. The top five winners were awarded during the Closing Lunch with Keynote Address on Wednesday 10th October 2018 by Nobel Prize-Winning Physicist, Professor Stephen Chu, EPCA President, Marc Schuller, and PlasticsEurope's Executive Director, Karl-H Foerster who was later joined by Caroline Ciuciu, EPCA CEO, to award the other five winners.



Systemic Solutions to Energy-Efficient and Climate-Resilient Cities

OFFICIAL OPENING BY EPCA PRESIDENT

EPCA President, Marc Schuller, Executive Vice President, Arkema France, welcomed 2,857 registered delegates to the EPCA's 52nd Annual Meeting in Vienna. Before introducing the theme of this year's Annual Meeting, Marc Schuller reminded the participants that compliance with competition law is one of EPCA's core values. That this compliance should be ensured at all times during the event, including one-to-one meetings and social events in the context of this Annual Meeting. Delegates should refrain in particular from discussing sensitive market information, unless it is legitimately in the public domain and that if in doubt, delegates can refer to EPCA's Do's and Don'ts guidelines, which are available in many different formats at the Annual Meeting or can contact an EPCA staff member directly.

Marc Schuller stated that the industry is both in interesting and challenging times, with a backdrop that includes the growing trade war between the US and China, rises in oil prices, and the negotiations around Brexit. But despite these uncertainties, EPCA remains focused on its mission: supporting the sustainable

development of the petrochemical industry. "That's why the theme of this year's Annual Meeting is: "Petrochemicals and the Low-Carbon Economy: Versatile Solutions for greater Sustainability." Our aim is to focus on how our industry can support the transition to a low-carbon economy by providing innovative and sustainable solutions that will enable the development of Smart Cities, Smart Mobility and Energy-Efficient & Climate-Resilient Society at large" Marc Schuller continued.

The transition towards a low-carbon, sustainable future for the industry will require changes in business models; diversification of energy and feedstock sources; development of innovative production and transportation processes; as well as change in culture and leadership, the EPCA President said. While recognizing the challenges and opportunities in the years ahead, he also noted that Europe has a strong record of innovation and that the importance of these topics was also highlighted in the new International Energy Agency report (The Future of Petrochemicals, Towards more sustainable plastics and fertilisers). The report further states that the products of the petrochemical industry are both essential to current and future

economies and future energy generation, the petrochemicals sector receives far less attention than it deserves. Clearly, the industry needs to raise its profile and achieve wider recognition for its ongoing contributions towards sustainability.

Before introducing the speakers, Session moderator, Nadine Dereza, the awardwinning business journalist and presenter, said the meeting was taking place as the Intergovernmental Panel on Climate Change issued a warning that there are just 12 years to avoid environmental catastrophe by limiting global warming to 1.5°C. She suggested that the challenge for petrochemicals is to persuade society that the sector's activities are both compatible with and contribute to achieving a low-carbon economy. To do that, it will need to manage emissions, help manage and mitigate waste - particularly plastic waste - by encouraging, developing and implementing recycling technologies, and win recognition as an enabler of renewable and low-carbon energy. But Nadine Dereza also wondered whether it will also require a paradigm shift in the way that the petrochemical and plastics sector is organised and operates.

KEYNOTE INTRODUCTORY ADDRESS: SENSEABLE CITIES: ENERGY & SUSTAINABILITY

Professor Carlo F. Ratti, Director at MIT Senseable City Lab, Founding Partner of Carlo Ratti Associati.

Architect and academic, Professor Carlo Ratti began by proclaiming his "passion for cities." While cities currently account for only about 2% of the world's surface area, they contain a little over 50% of its population, and account for 75% of its energy use and 80% of its CO₂ emissions. Given that this trend is likely to accelerate, Professor Ratti said it is his mission to try to make cities more sustainable.

Back in the 1990s, Carlo Ratti recalled, the talk was about the coming of a "virtual world," a "digital revolution," and the "death of distance." In this new age, physical space would become less important, and one pundit, George Gilder, even predicted the death of cities, suggesting urban centres were "the left-over baggage of the industrial age."

We now know how wrong these predictions were, Carlo Ratti continued. For example, this century, China is likely to build more urban infrastructure than has hitherto been built in human history. In fact, what we are experiencing is a confluence of digital and physical space – exemplified by the Internet of Things – that is impacting the way we can design, operate or change the cities in which we live, making them more sustainable. Indeed, the data we can gather through digitisation has the potential to enable us to "close the loop and develop a circular economy."

To illustrate his point, the MIT professor turned to waste management. While we

might know everything about the global supply chain involved in the production and use of computers, what do we know about the "removal chain" that occurs when a computer is disposed of, Carlo Ratti asked. At this point, he contrasted the human-and-horse-dependent rag-picking and gleaning of garbage in New York City in 1900 with a modern processing and recycling unit using robotics and electronics to sort and separate waste. Despite their apparent difference, Professor Ratti noted that they both relied on removal chain resilience because when this breaks down, "garbage piles up."

In the USA today, Carlo Ratti noted, there is a correlation between waste and recycling facilities, which are often closely located in or near cities, where recycling rates can be high as a consequence of the high cost of land mitigating against landfill disposal. But how much do we really know about what happens to our urban waste in the "removal chain"? To answer that question, MIT developed a project called "Trash Track." Centred in Seattle, the project used "trash tags" – electronic wireless sensors – to track the



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distances travelled by 3000 waste objects provided by 500 volunteers. Trash Track's aim was to find the final destinations of these waste objects and increase awareness of sustainable practices.

Two key revelations were the huge distances travelled by some articles and their transit times, which Carlo Ratti illustrated with a video showing a network of steadily extending lines as the waste objects' movements were tracked around Seattle, and across Washington state and the wider USA and beyond. For example, while a yoghurt pot travelled 35 miles to a recycling centre in just under four days, two printer cartridges took different routes and three weeks to get to the same destination in Baja California, one going direct, the other via Chicago. Cell phones were tracked moving from Seattle to the Midwest, Florida and New England. Lithium and alkaline batteries moved thousands of miles via way stations. And while much of the waste remained close to Seattle or within Washington state, a significant number of objects were tracked over a two-month period travelling eastward across other states in a series of stop-go movements. Many of the sensors were tracked to processing and recycling centres, but many of the sensors and the objects they tagged ended up in landfills. "So what lessons can be learned from the Trash Track project?" Carlo Ratti asked. First, that the complexity of the disposal and disassembly processes for certain objects may mean they travel huge distances. Second, that data is a powerful agent for change. So, if we understand what happens to items in disposal or recycling, then we may make provisions to change those processes, he said. For example, if we know the plastic bottles used to distribute and sell water are being landfilled, then perhaps this will deter us from drinking water from plastic bottles, the professor suggested.

Third, the project revealed that a lot of waste was going to ports and being exported. Carlo Ratti mentioned a PBS television report that documented the export of the USA's electronic waste cargoes to various destinations around the world, where they were to be recycled or dumped, and where treatment or disposal methods might be either legal or illegal. This underlined the need for governmental intervention to impact and improve waste management.



Overall, Carlo Ratti's point was that by using new technology to generate data, it is possible to gain a detailed understanding of the "removal chain" and act to make changes towards greater sustainability.

Outlining the fourth Trash Track project lesson, Carlo Ratti provoked sustained amusement and laughter. He explained that when the MIT team suffered a significant computer theft, the thief was unaware that the devices were equipped both with GPS tracking systems and web cams that could film any user, authorised or otherwise. In showing a short video, Professor Ratti talked the audience through the process of tracking and detection that led to the recovery of computers and the apprehension and conviction of the thief.

HOW PETROCHEMICALS CAN CONTRIBUTE VALUE TO SOCIETY

Saori Dubourg, Member of BASF SE's Board of Executive Directors, Responsible for Agricultural Solutions, Construction Chemicals, Bioscience Research and the Region Europe.

Following the period of globalization, which has seen industry players expanding production and distribution worldwide in pursuit of volume growth, Saori Dubourg said a tectonic shift is underway as the chemical sector adds a new focus: delivering value. We are living, she said, in an "Age of Value to Society," which means that the industry needs to demonstrate and quantify the value it provides to society in economic, social and environmental terms through the usage of resources, conduct of operations and its business culture. A key to meeting this challenge will be





action and implementation of policies, technologies, processes and products that provide concrete examples that the industry is delivering value to society.

Saori Dubourg highlighted the main trends the chemical industry will need to address through to 2030, such as climate friendly materials in construction or energy efficiency in buildings. With forecasts indicating that in 10 years 67% of the world's population will live in cities, Saori Dubourg said we need to improve energy efficiency, mitigate CO₂ generation, and improve resource usage in urban centres. By way of a response to these challenges, Saori Dubourg said she would address three questions: How can we use our existing buildings more efficiently? How can we rethink the planning and construction of new city buildings? How can we measure our value impact?

Today, buildings account for around 40% of global energy consumption and a third of CO₂ emissions, Saori Dubourg continued.

Given that most of the developed world's cities have significant stock of decades-old housing and buildings, upgrading - using chemical industry solutions - offers an opportunity to enhance energy efficiency and lower associated CO₂ emissions.

As an example of what can be achieved through effective building renovation, Saori Dubourg offered a quick review of measures implemented to improve the environmental performance of the Brunck housing district adjacent to BASF's Ludwigshafen complex. Although dating back to the 1930s, most of the district's buildings are 1950s apartment blocks. In 1996, after consultations with the residents, BASF and the local city and state governments began implementing a plan to improve living standards and cut energy consumption through measures including installation of high-performance wall insulation panels, triple-glazed windows with an inert insulating gas between panes to improve heat retention, and insulated PVC window frames.

Starting from an average heating consumption of 21 litres of heating oil per square meter per year, renovations reduced energy consumption to on average 5 litres, thereby dropping overall energy

consumption by about 80%. Moreover, ecological payback was achieved within one year, and within ten years of the changes being implemented, ${\rm CO}_2$ emissions were also down 80%, Saori Dubourg noted.

Turning to new buildings, Saori Dubourg gave examples of how new construction materials and predefined building modules can improve environmental performance. First, she described how BASF's Green Sense® concrete has lowered the CO₂ footprint by mixing fillers with cement while also increasing flowability, extending the lifecycle of buildings and lowering costs. Supplied as a key building material for the One World Trade Centre in New York City, Green Sense® concrete saved the energy equivalent of 7,000 households. It includes recycled materials and can be optimized for specific applications and formulated according to regional availability of ingredient materials. Next, Ms. Dubourg noted the potential of smart building planning, which could involve the use of predefined building modules, which are simple to install and can be reused, while keeping the CO₂-intense building materials concrete and reinforcement steel untouched.

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Saori Dubourg continued her speech by explaining how BASF measures its economic, social, and environmental contribution along the value chain, which includes direct and indirect suppliers to BASF, the company's own operations, and direct customers in industries supplied by BASF. The approach is called Value-to-Society and aims to reflect how BASF's business activities change the well-being of people expressed in monetary terms. In 2017, BASF increased its total net positive impact on society by 9% compared to 2016.

Looking ahead, and in the face of accelerating urbanization, particularly in Asia, Saori Dubourg said she remained optimistic that chemistry can help cities find solutions for enhanced energy efficiency and reduced greenhouse gas emissions.

THE SMART CITY CHALLENGE

Yousef Abdullah Al-Benyan, Vice Chairman and CEO of SABIC

Opening his address, SABIC's Chief Executive Officer Yousef Abdullah Al-Benyan said we are living in a unique period of change as accelerating global industrialization also drives rapid increases in urbanization. By 2050, when the global population is forecast to have reached 9 billion, around 60% will be city-dwellers, he said. "As an example: India will have an additional 315 million people, which is almost equivalent to the USA's current population, and 70% of them will be living in cities."

Urbanization is creating a series of challenges that face not only the chemical sector, but also societies and governments, Mr. Al-Benyan continued. With the growing weight of middle-class aspirations, we are seeing an upsurge in demand for energy to meet a range of needs such as heating, air conditioning, and transportation. For the chemical sector, this also means an emerging market place – for new materials and innovative technologies that enhance energy and resource efficiency, for example, and contribute to the creation of sustainable, Smart Cities.

Recalling SABIC's history, Yousef Abdullah Al-Benyan said that sustainability had been a core driver for the company since its birth, which was predicated on using rather than flaring the gas from oil production in Saudi Arabia. Subsequently, SABIC has continually striven to achieve improvements in its environmental performance – enhancing resource and energy efficiency, and water and air quality - and in terms of social responsibility.



"As a global leading company at the vanguard of the petrochemical industry, SABIC believes that successful companies of the future must integrate business with sustainable values," said Yousef Abdullah Al-Benyan. Accordingly, he said SABIC has used the UN's Sustainable Development Goals to align the company's business and sustainability strategies, which has resulted in key priorities including portfolio assessment and design, developing renewable energy products and systems, enhancing carbon efficiency, pursuing a circular economy in plants and projects, and overall sustainability. "The main objective of Smart Cities is improving environmental quality in the urban space by reducing CO₂ emissions, reducing waste, optimizing energy consumption by creating energy efficient buildings and home appliances, and increasing the use of renewable energy," Yousef Abdullah Al-Benyan said. "SABIC has been thinking about how to accomplish this for quite some time."

In fact, all of SABIC's sustainability efforts tie in with the priorities for Smart Cities, which Yousef Abdullah Al-Benyan listed as reducing CO₂ emissions and waste generation, optimization of resource use, and a focus on renewable energy. In this regard, he offered another example of SABIC's contributions to sustainability and Smart Cities: its "house in the desert" - or "Home of Innovation" which is an energy-neutral single-family home generating as much energy as it consumes. Built in Riyadh's Techno Valley, the house offers a template for comfortable, modern and sustainable living, particularly in hot, arid climates. "Between its generation of renewable energy and energy efficiency," he said, "100,000 Demonstration Homes would save the equivalent of 1.8 million barrels of oil per year."

In closing his speech, SABIC's Yousef Abdullah Al-Benyan recalled that last year, Saudi Arabia announced plans for a new \$500bn smart, sustainable megacity on a 26,500km2 site located on its north western Red Sea coast adjacent to Jordan and Egypt. Called "Neom", the new city will be powered by renewable energy and designed to enable business and industry to develop in harmony with sustainable living for its inhabitants. Conceived as a means of further shifting Saudi Arabia's economy away from a reliance on oil

and gas, Neom's creators envisage the development of several key economic sectors – energy, water, mobility, food, advanced manufacturing, biotechnology, media and entertainment, and technological and digital sciences – of which SABIC will focus on five. The aim is to have Phase 1 development completed by 2025.

Concluding, Yousef Abdullah Al-Benyan said that while Neom might not offer a model for others to follow the new city will create a vision for the world in terms of creating sustainable Smart Cities for the future.

QUESTION & ANSWER SESSION:

Q: Are we seeing a transition from volume to value in terms of chemical production?

Saori Dubourg: "Volume is not going away. As the population grows and development increases, volumes will increase." But she said there will be greater emphasis on new technologies needed to meet new challenges and referred to the examples given in her speech, to illustrate this. Ms. Dubourg also suggested that it is increasingly important for the industry to explain what it does, how it operates and produces, and the contributions it makes to society. "We will need to address the emotional and intellectual needs of society."

Q: Is the petrochemicals business model changing, from long-term, heavy investment to a more flexible, consumerfocused approach?

Yousef Abdullah Al-Benyan: The industry needs to think outside the box, beyond a business-to-business mentality, and make more investment in a business-toconsumer approach, Mr. Al-Benyan said. "For example, we are already talking about solutions rather than products." While feedstock remains an essential ingredient, a region such as Europe, whose strength is in technological innovation rather than feedstock production, should focus even more on innovation, he said. Given that the Middle East and the USA are feedstock rich, it is hard for Europe to compete on costs, which is why the innovation focus makes sense.



Q: Is more collaboration the answer to more innovation and sustainability, and if so, how will these play out between governments and industry?

Carlo Ratti: "More collaboration is vital!"
But Professor Ratti accepted there are intellectual property and competition challenges that need to be addressed. However, he pointed to Singapore as an example of government and the public sector as a whole cooperating closely with the private sector in an effort to achieve growth and sustainability.

Saori Dubourg: Agreeing with Mr. Al-Benyan, she offered the example of BASF's collaboration in a new "Architects' Day". Designed to be an annual event in Germany, this is bringing architects and designers and a range of experts from across the construction sector together with product suppliers to discuss potential solutions to current and future problems and increase the sustainability of the built environment. However, Ms. Dubourg also emphasised the need for industry to increase its engagement with government, NGOs, customers and citizens. Some challenges require global responses, however, which is difficult if many countries take a different approach to a common problem. Saori Dubourg offered waste as an example of where the complexity and differences in governmental approaches make solutions



problematic. Another example is climate change. She questioned whether keeping global temperature rise to 1.5°C was possible given the myriad approaches to ${\rm CO}_2$ mitigation, and the lack of a global ${\rm CO}_2$ pricing system.

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Q: Are some regulations unrealistic, and can more global co-operation regarding regulations and sustainability solutions be encouraged?

Yousef Abdullah Al-Benyan: Suggested that the industry, by company and via its trade associations, needs to broaden discussions by involving more people and organisations from outside the chemicals sector. "We need to understand their perceptions and expectations of the industry and we need to explain what we do and what is possible in addressing these broader goals." On regulations, Mr. Al-Benyan said it is important that regulators understand what is and what is not possible for industry to deliver at any point in time. Targets are good to drive change, but they need to be realistic, he said.

Carlo Ratti said he thought it might be more productive to identify what consumers rather than governments want, as they are not always aligned. Professor Ratti suggested that perhaps this would be a better way to develop general frameworks for regulation and

to respond to, say, public demands for more recycling or new product systems.

Q: How realistic is renovation rather than innovation to solving our problems? Saori Dubourg: Renovation is absolutely realistic in terms of achieving the sustainable, Smart City, Ms. Dubourg insisted, but added that it can also work in tandem with innovation. Planning and vision are key, but also mindset shifts to meet challenges. "I think renovation is a big opportunity, and I'm very optimistic about the future."

Q: Do City Mayors and Planners have a role to play in achieving the Smart City? Yousef Abdullah Al-Benyan: Mayors have great involvement and influence regarding day-to-day issues management and also the ability to drive solutions, Mr. Al-Benyan said. Take parking - and by implication CO. emissions from cars - for example: In some cities parking accounts for up to 60% of space, and the way to have less cars and less CO₂ is better mobility in terms of public infrastructure and provision and private sector responses, such as the electric car. But comprehensive solutions are difficult and expensive, so there is a need to identify priorities and implement step-by-step approaches to these challenges, Mr. Al-Benyan said.

O:There are many Circular Economy think tanks, but how realistic is the concept? Saori Dubourg: Data indicates that the idea has strong traction among consumers, industry and society as a whole, she responded. The key is data application to develop processes, frameworks and technologies to implement the Circular Economy. Progress is being made and there is a lot of cross-fertilization. There are examples in plastics, in smart agrichemicals and biotechnology.

Yousef Abdullah Al-Benyan: "The Circular Economy is essential! We need to re-use and recycle," he continued, noting the need for "significant increases in plastics recycling by Industry and consumers. Society as a whole needs to adopt a cradle-to-cradle approach rather than just looking at the production angle."

Q: What were the panellists closing thoughts and advice?

Carlo Ratti's answer came as a question, as he urged us to look for examples in nature. Given that once plastic is in the ocean it is almost impossible to retrieve to prevent contamination of living organisms, shouldn't we be thinking about different forms of packaging such as those smart containers provided by oranges or coconuts, he asked?

Saori Dubourg suggested we try to balance opportunities with threats. For example, can we match biodegradable plastics packing with the need to deliver fresh food in good condition to consumers? Yousef Abdullah Al-Benyan urged the industry to review and renew its operating models, balancing the need for cost control with the need for investment in new technologies to meet the challenges facing cities today and in the future.

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Talent & Diversity: Essential Elements to be a Sustainable, Innovative & Attractive Employer

INTRODUCTION BY TDIC CHAIRPERSON

Nathalie Brunelle, Chairperson of EPCA's Talent and Diversity Inclusion Council (TDIC), and Senior Vice President Corporate Affairs, Total Petrochemicals and Refining

EPCA's TDIC Chairperson, Nathalie Brunelle, opened proceedings by noting that the Annual Meeting's previous Sessions had confirmed the key role played by petrochemicals in enabling progress towards a low-carbon economy. The industry's materials have the potential to provide solutions to sustainability in the 21st century in areas such as energy efficiency, water use, living conditions, and Smart Cities, she said.

However, Nathalie Brunelle questioned the way the industry attracts and nurtures talent and fosters diversity in the workplace. In this regard, Nathalie Brunelle highlighted three of the UN's Sustainable Development Goals (SDGs), which she said posed direct challenges to the petrochemical industry.

"Take Goal 5, which is to achieve gender equality and empower all women and girls," Nathalie Brunelle said. "It's about educating girls, but one of the targets is quite precise: it's to ensure women's full and effective participation and equal opportunities for leadership at all levels of decision making." In fact, when three years ago EPCA surveyed the industry, women held just 15% of the jobs at "the top of the pyramid" in industry management roles, she continued.

"EPCA's new "Age Inclusion & Diversity" report highlights that there is a clear link between an inclusive & diverse work environment and brand attractiveness"

NATHALIE BRUNELLE

Chairperson of EPCA's Talent and Diversity Inclusion Council (TDIC), and Senior Vice President Corporate Affairs, Total Petrochemicals and Refining

"Goal 8 is about full productive and decent work and economic growth. One of the targets is to achieve a high level of economic productivity, full diversification, technological upgrading and innovation," Nathalie Brunelle said. "The facts are that nearly 500 million jobs are needed globally for new entrants to the labour market by 2030." EPCA's TDIC Chairperson noted that the chemical industry can contribute to this goal by adding value, and by creating downstream opportunities for growth and jobs through innovation.

"Goal 12 is about responsible consumption and production. Targets include environmentally sound management of chemicals, and also of all waste through the lifecycle," Nathalie Brunelle said, adding that the industry can certainly make a positive contribution to the circular economy.

By working for 18 months on Age Diversity, the Talent Diversity & Inclusion Council has touched on these topics and has highlighted that there is a clear link between an inclusive and diverse work environment and brand attractiveness. Nathalie Brunelle said that the new report is now available examining "what it means to have five generations of people working under our roof and how that transforms our industry."

Before introducing the keynote speaker and panellists, session moderator, Nadine Dereza, then offered a quick summary of the EPCA's new Age Inclusion and Diversity report. While noting the positive benefits of intergenerational cooperation and the mix of experience with new ideas and practices found within the industry's workforce, the report highlights the challenge of replacing an ageing workforce with new young talents in a very competitive labour market.

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KEYNOTE ADDRESS: WHY SUSTAINABLE MINDSETS MATTER

Professor Wayne Visser holds the BASF-Port of Antwerp-Randstad Chair in Sustainable Transformation and is Professor of Integrated Value at Antwerp Management School. He is also Fellow of the University of Cambridge Institute for Sustainability Leadership.

Keynote speaker Professor Wayne Visser offered the delegates both bad and good news. The bad news is that businesses are facing several crises - a crisis of engagement, a crisis of inclusion, and even a crisis of trust, which can negatively impact outcomes from the bottom line to recruitment. The good news is that these crises can be overcome if company leaders embrace and embed sustainability into their mindsets, business goals and systems.

Today, many businesses are facing a crisis of engagement, Professor Visser said. Taking examples from several surveys, he pointed out that: 85% of employees worldwide did not feel engaged with their work; just 14% of US employees agree that their employer's values are aligned with their own; 66% of 18-35-year olds and 83% of 30-35-year olds in the UK were unhappy at work, and 45% of all employees were considering a career change.

The consequences of this disengagement are serious, Wayne Visser continued. They include higher absenteeism, more errors and accidents, lower productivity and profitability, reduced job growth, and a potential drop in share price over time of up to 65%.

There is also a crisis of inclusion, which Professor Visser highlighted with examples of gender inequalities in the workplace. Whereas women account for around 40%-60% of the total workforce and around 35%-45% of management positions in sectors such as health, education, legal, public administration, and legal, in the manufacturing sector men outnumber women employees by three to one, and just 18% of management roles are filled by women. Overall, in terms of economic participation and opportunity there is a 42% gap between men and women. Furthermore, men's pay has increased faster over the past 10 years than women's, and at present levels it will take women 217 years to close that gap.

Businesses are also facing a crisis of trust and perception, which is particularly acute for the petrochemical and plastics sector he suggested. Wayne Visser illustrated this problem with a slide showing two pictures. One was the cover of National Geographic magazine headlined, "PLANET OR PLASTIC? 18 billion pounds of plastic winds up in the ocean each year. And that's just the tip of the iceberg." An iceberg was represented by a plastic bag mostly submerged but with a corner poking out from the ocean's surface. The other picture showed a huge blue whale sculpture about to leap from a canal over a bridge in Bruges, Belgium. The whale is made of waste plastics recovered from the sea. Accepting that the industry does not cause plastic waste disposal problems, he suggested the smart response - consistent with product stewardship and life cycle responsibility - is to offer solutions in the form of redesign (e.g. bioplastics and biodegradable plastics), reuse, recycling and contributing to the circular economy.

Having outlined the bad news, Wayne Visser turned to the good: these are all issues that can be addressed and mitigated, he said. The key, Professor Visser insisted, is sustainability, which is both a rich source of employee engagement and inspiration and can also deliver a significant range of business benefits. To illustrate this and pinpoint some key activities, he offered some snapshots from the 2018 Sustainable Change Survey into sustainability among businesses in Belgium, which was produced in collaboration by Antwerp Management School and ING. The report shows that sustainability is increasing employee engagement and pride, while also making companies more attractive employers. Other gains include enhanced company image, better cost control, increased compliance, competitor differentiation, more innovation, and higher revenues.

Focusing on social sustainability in the workplace, Wayne Visser noted that companies in Belgium are pursuing a range of activities aimed at enhancing employee recruitment and retention. Two thirds said they were focused on employee wellbeing, 51% on the employability of their workers, 44% on employee cultural diversity, and 37% on supporting causes with a social goal. Some 31% look to employ people with labour market disadvantages, 27% enable their employees



to volunteer, while 18% are developing new and innovative products with a social quality.

However, Wayne Visser noted that a 2014 Cranfield University study indicates there is a leadership "generation gap" around the implementation of sustainability which relates to beliefs about the purpose of business. For example, 88% of current leaders and 93% of future leaders believe businesses should have a social purpose. But when asked if businesses have a clear social purpose, nine out of 10 current leaders say they do, while two out of 10 future leaders agree. Furthermore, 50% of future leaders believe that businesses focused solely on economic value will in future have no competitive advantage.

While current and future leaders see profit and shareholder value as the keys to business success today, Professor Visser said future business leaders also believe that future success will be based on innovation, talent development and social and environmental impacts. But if profit needs to be combined with purpose to achieve success, what are the barriers? Primarily, inconsistent government engagement and management attitudes, according to the Cranfield study. Looking ahead, 50% of future leaders feel that prioritising a societal and environmental purpose in combination with economic value will be rewarded with more engaged employees, more innovation, more trust in the business and greater relevance to the next generation. Interestingly, to make the shift towards greater sustainability, current and future leaders have the same advice: education and changing mindsets.

But while changing mindsets is a challenge, Wayne Visser outlined some findings from the UK's University of Cambridge's Institute for Sustainability Leadership that identified seven key characteristics that define sustainability leaders. They are: systemic understanding, emotional intelligence, values orientation, compelling vision, inclusive style, innovative approach and long-term perspective. To provide supporting context, Professor Visser noted that while 68% of business leaders with sustainability expertise say sustainability investments have delivered financial benefits, only 32% of those considered sustainability novices report similar results.

However, having listed key sustainability leadership skills, Wayne Visser questioned whether they are being taught sufficiently in management and leadership development courses. He described how in 2017 the Corporate Responsibility Centre within the

Antwerp Management School rebranded itself as the Sustainable Transformation Lab and subsequently launched corporate leadership groups (on the circular and wellbeing economies) that reflect the needs of innovation and sustainability. The Lab is fostering outreach and collaboration for responsible management education, and also has a voluntary student ambassador campaign to promote the SDGs in companies and the community. It is even taking the ambassador campaign to China. Wayne Visser noted that the chemical industry is now stepping up its sustainability efforts and offered four quick examples of how these can inspire future leaders. In the Port of Antwerp, QPINCH has technology that can capture and reuse waste heat from industrial processes to generate steam and water, while reducing CO₂ emissions. Covestro has technology to produce polyurethane foam components made by absorbing CO₂. Catalyst producer, Umicore uses waste materials from spent catalysts and metals refining.

BASF, meanwhile, is tracking products through the supply chain and implementing what it calls "Sustainable Solution Steering." This categorises products and solutions according to sustainability criteria: "Accelerators" make a substantial sustainability contribution in the value chain; "Performers" meet basic sustainability standards; "Transitioners" have specific sustainability issues which are being addressed; and "Challenged" have specific sustainability concerns and action plans are being developed.

Summing up, Wayne Visser said companies embracing sustainability are more likely to be able to attract and retain new talent by providing exciting career options.

Outcomes for workforces include improved engagement and morale, increased loyalty, lower employee turnover and thus less costs in recruitment.

Professor Wayne Visser further mentioned that tackling the UN's Sustainable Development Goals (SDGs) is expected to open up market opportunities worth an estimated \$12 trillion, while decarbonisation

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will boost the global economy and generate up to 28 million jobs by 2050.

However, Professor Wayne Visser warned that companies should avoid "rainbowwashing" – talking but not walking the SDG talk – and look to create "integrated value" by finding ways to achieve innovation synergies through secure, smart, shared, sustainable and satisfying solutions. The key to achieving integrated value is collaboration, Wayne Visser said: "If you want to go fast, go alone. But if you want to go far, go together!" Looking ahead to 2050, the professor offered a positive outlook for an industry that offers innovations and solutions for sustainability, even if it may not be recognized at the moment for the contributions it makes.

PANEL DISCUSSION:

Reflecting the topic of age inclusion and diversity, Nadine Dereza invited three women – two young recruits to the industry engaged in management roles, and an industry veteran now specializing

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in chemicals recruitment – to join Professor Visser for a panel discussion and question and answer session.

To start the session, Nadine Dereza introduced Charlie Fryer, Digital & Social Media Strategy Adviser, Shell. Ms. Fryer joined Shell in 2015 and has subsequently worked in areas such as reputation management, crisis management, audience research and social media strategy. The moderator asked her to outline how Shell champions, attracts and retains a diverse and inclusive workforce. "It's a big question, and the answer isn't simple," Charlie Fryer responded, explaining how Shell uses a range of options to appeal to a diverse audience from different demographics. "Shell takes a long view, investing heavily in STEM initiatives around the world, to motivate and inspire young people to see themselves in our industry, and we have leaders who can reflect the values we see in society around us and act as role models for underrepresented groups in the company." Diversity, Charlie Fryer observed, "is a huge cultural imperative for the company."

Asked how social media is transforming internal and external communications for Shell, and in attracting new, diverse talent, Charlie Fryer said that while the company continues to use campus outreach and internships to recruit, social media provides an important channel for engagement. "It allows us to develop messages that address the concerns and aspirations of specific groups within the skill pools we seek to recruit. It's an environment in which we are still learning our craft and how to position ourselves so that we can engage in conversations and start a dialogue."

Questioned about closing the gender gap, the Shell social media adviser spoke about how her team was tasked to come up with a campaign that explored the gender gap in engineering. While there was already a focus on early years intervention to promote STEM subjects and so on, there was no discussion about why engineering is losing so many female engineers. "Women make up 20% of engineering graduates globally, but only 11% of the engineering workforce." Research shows that this is due in many ways to unconscious bias, and

the environment engineers are working in," Charlie Fryer elaborated.

At this point, the audience was shown a Shell video, which highlights the gender bias, both conscious and unconscious, that girls and women are often subjected to, and which may discourage them from taking up or continuing in a STEM-related career. These ranged from unwelcome and unwarranted comments – predominantly from men - about weight or clothing, to engineering being "a man's job," getting a job "only because you are a woman," or even "why doesn't your husband just let you stay home?"

However, the video, which stirred considerable reaction in the appreciative audience, also offers examples of comments that are far more positive and encouraging for women considering a job in engineering or technology-based industries. And as the main narrator, a young girl, makes clear: women are just as capable as men. Charlie Fryer noted that the video was made to "start a conversation" that is industry-wide, but also welcomed any positive recruitment impacts it may be having. She said the response was overwhelmingly positive, and the video has certainly delivered on its aim.

Nadine Dereza then introduced Gabriella Isidro, Business Development Manager, **INEOS Olefins & Polymers Europe North**, who has been employed by the company since 2013 having completed a degree in Chemistry at the University of Warwick, UK. Since joining INEOS, Gabriella Isidro has held three international commercial positions, and is currently based in Switzerland. She recounted how she had joined INEOS's commercial management programme for graduates, which is designed to provide recruits with a broad range of experience across business disciplines and locations. Ms. Isidro said the programme really helps young employees to get to know INEOS's business from "the ground up," gives them responsibility from day one, and also provides direct access to senior management.

Asked about her "first point of entry experience," Gabriella Isidro said that while INEOS's leadership is currently primarily male, the company without a doubt provides a welcoming and supportive environment for new recruits of both genders. "I didn't come into the company feeling that being



a young female recruit was an issue at all. The company invests in its young managers regardless of gender." She also pointed out that her current boss is a woman, and that women are rising steadily through INEOS's management ranks.

At this point, the audience watched another video which showed some clips from an INEOS teambuilding exercise for its recruits. This, Gabriella Isidro explained, entailed a week-long visit to Namibia and a 350km cycle-and-run across the desert. Training for the exercise took 9 months, and the aim was to provide both a challenge and to encourage networking and teamwork amongst INEOS's engineering and commercial graduate recruits. In fact, Ms. Isidro said that for her the Namibia experience provided evidence for Professor Wayne Visser's suggestion that, "If you want to go fast, go alone. But if you want to go far, go together." This challenge, Gabriella Isidro said, "really tests your limits, but it also encourages you to think outside the box" and expands your ideas about what you can achieve both at work and in life."

Gabriella Isidro also talked about INEOS's "Go run for fun" programme, which is a

charity that encourages young children to get active in their daily lives, and currently has got over a million young people running a daily mile (or 1500 metres). She also noted that recent research supports the theory that regular exercise can impact academic attainment.

The session's final panellist was Frederika **Tielenius Kruythoff, Managing Director** of Korn Ferry Executive Search in the **Netherlands and Senior Client Partner** responsible for the EMEA Chemical as well as Agri practice. Prior to her current position, Mrs. Tielenius Kruythoff held several senior management roles in the chemical, food and beverage sectors, working for companies including Royal DSM, Ineos, Unichema and Ciba-Geigy. She mentioned that Korn Ferry has been doing employment research, looking at the impact of talent recruitment, in support of the European Chemical Industry Council's (Cefic) Mid-Century Strategy report, and has combined this work with a broader study on the availability of skilled labour in the global manufacturing industries in the period 2025-30. From these studies, Korn Ferry has identified that from 2030 there will be a shortage of skilled labour across

the industrialised world, except in India, where there will be a surplus. In terms of impact, throughout the manufacturing sector worldwide unrealised output could reach 600 billion US dollar.

Asked about findings regarding women in manufacturing, Frederika Tielenius Kruythoff said that a survey of 57 women chief executive officers showed that on average they were four years older than their male counterparts when they got their positions, that only 12% had an ambition to be a Chief Executive, and that many of them were encouraged to seek the top jobs by male colleagues who believed they had both the capacity and capability to take these roles. Frederika Tielenius Kruythoff said that women tend to pursue specialized careers as they are not always encouraged to seek general management positions with profit and loss responsibility, which are key to gaining experience for top business roles. Asked to comment on challenges facing the industry in future, Shell's Charlie Fryer said the energy sector has many, from navigating the energy transition to encouraging young people to see themselves as having fulfilling careers in the industry. She noted that there is a perception that it is the "tech giants"

who are offering young people exciting jobs, with international experience and good personal development prospects. Businesses in the energy and chemical sectors need to explain that they can offer the same opportunities, Ms. Fryer said. Charlie Fryer suggested that appealing to a 'millennial' audience requires appropriate use of vernacular and tone with an injection of punch, humour and sarcasm. If energy and chemical companies want to attract talent, they need to be offering long-term but varied, flexible careers, and demonstrating a vision and purpose that reflects those of a younger generation.

Professor Wayne Visser agreed that to attract recruits from the younger generation, company and industry messaging needs to tell stories in an entertaining way that is not perceived as just PR.

Gabriella Isidro added
that it is essential to "make
science fun, interesting,
exciting and sexy." She also
urged the industry to get out
into schools, and to invite
school age children and their
teachers onto their sites so
that they can get a feel for
the chemical sector.

To Illustrate this, a short video was shown of the Tu Was schools outreach programme developed by the University of Berlin, and which INEOS has supported for several years. Children aged between six and 12, are enabled to interact with science experiment boxes that prompt questions as they seek answers. Gabriella Isidro and Charlie Fryer both stressed the value of showing children that science offers solutions to the challenges facing society today.

Asked what companies should do to make themselves 'employers of choice,' Frederika Tielenius Kruythoff said they need to have a clear direction, which people can understand, and which is linked to a purpose and a set of values that current and potential employees feel they can be aligned with. She also emphasised the value of transparency and consistency in company messaging particularly in view of the challenges the

chemical sector has in attracting and competing for talented new recruits. Noting that only 20% of chemistry students are joining the industry after graduation,

Frederika Tielenius Kruythoff said the industry needs to go further by developing outreach and messaging programmes that encourage people to join and stay in the chemical sector.

As a linguist and someone without a background in chemistry or engineering, Charlie Fryer was asked about the process through which she was recruited to Shell, and whether she would change it.

Her aim, she said, was to have a flexible, international career with dynamic options, and which would have an impact on the issues the world is facing. However, Ms. Fryer was not considering working in the energy and chemical sectors until a chance meeting with a former Shell Communications professional who had a similar academic background. "The experiences she shared with me opened my mind to a new way of thinking about what I could do in the future," Charlie Fryer said.

Having decided to look further into the possibilities of working for Shell, she attended an assessed recruitment day, which mixes potential hires with existing employees. This process gives career seekers an opportunity to get a real feel for Shell while the company's existing employees can help assess whether a potential recruit will be a good fit and has the requisite strengths. Relating her experiences since joining Shell, Charlie Fryer said that she was surprised at how quickly she was able to have a voice in an intergenerational working environment, "working in Diversity and Inclusion has enabled me to make a real contribution."

Gabriella Isidro echoed Ms. Fryer's experience, saying she felt INEOS listened to her, that she was "not just a number," and that the company's flat organisational structure gives new employees access to Senior Managers. She also praised INEOS's two-way mentoring scheme.

Asked for his views on the importance of reputation for employee recruitment and retention, Professor Visser offered three examples. After "Diesel-gate," VW's reputation suffered, and BP had a similar experience after the Deepwater Horizon disaster, he noted. In contrast, Wayne Visser noted that Unilever has benefited significantly from its sustainability plan, which has seen the group double its size while halving its environmental footprint. "Today, 1.7 million people a year apply for jobs with Unilever." Professor Visser emphasised the importance of "belief in brand," remarking that electric car maker Tesla has a higher stock market value than GM despite producing a hundred times fewer cars.

Asked if the UN's Sustainable Development Goal 4 – which is to ensure inclusive and equitable quality education and promote lifelong learning opportunities for everyone – is the most important, Wayne Visser said: "No! They are all important. You need to think about them together, and as a system for sustainability." However, making a related point, INEOS' Gabriella Isidro suggested the industry's approach to education and the content of STEM education courses can still be improved, and urged companies to be proactive rather than reactive.

As the session drew to a close, Nadine Dereza asked the panel for their final calls to action.

Korn Ferry's Frederika Tielenius Kruythoff urged companies to address the whole talent pool and make career offers that reflect young people's visions and values, while INEOS' Gabriella Isidro remarked that there is no room for complacency when it comes to diversity and recruitment.

Shell's Charlie Fryer stressed that while company policies' and structural change are vital, so too is taking individual responsibility for creating an inclusive environment.

Antwerp Management School's Professor Wayne Visser offered this advice: "Stop drinking the Kool Aid, and stop 'group think'! Focus on societal costs and on scalable solutions."



Innovation and Innovative Concepts for a more Sustainable Supply Chain

INTRODUCTION BY SCPC CHAIRPERSON

Opening the session, Johan Devos, Chair of EPCA's Supply Chain Program Committee (SCPC) and Sales Director Europe, Bertschi AG, welcomed delegates to hear about and discuss both supply chain issues and solutions in the drive for the low-carbon economy and sustainability. He also welcomed the young people who had taken part in the European Youth Debating Competition.

Johan Devos also mentioned EPCA's recent Supply Chain and Logistics Workshop, Digitisation in the Petrochemical Supply Chain, which was held earlier in the year, noting the report from this meeting is now available in hard copy and accessible online via EPCA's website. Before handing over to speakers and panellists, he said the continuing prominence of the Session at EPCA's Annual Meetings reflects the

importance of Supply Chain and Logistics as a key element of business strategy for the petrochemical sector in the age of ongoing globalization.

KEYNOTE ADDRESS: Going Green is not black and white

Professor Yossi Sheffi, Elisha Gray II Professor of Engineering Systems at MIT, Director of the MIT Center for Transportation & Logistics

Professor Yossi Sheffi said he wasn't about to tell the audience what must or not be done in the cause of sustainability. Rather, he would try to deliver a realistic assessment of what can be achieved in the face of a range of economic, social and environmental pressures and the

complexities of measuring and adjusting sustainability performance.

"It's all about the supply chain," he continued. Why? "Because, two thirds of carbon emissions for most companies occur upstream in the supply chain, in the activities of their suppliers. However, for some products, most of the emissions occur downstream in the use phase by customers. So, looking just at a company's environmental impacts is misleading." For example, "Coca-Cola were very happy that they reduced the use of water from 6 litres per litre of Coke to 3 litres, which was a 50% reduction and a great achievement. But at the same time, they used 28 litres of water for 1 litre of Coke just to grow the sugar cane. So, unless you look at the whole supply chain, that's misleading." In the past, Apple's phone service appeared carbon neutral, but that was clearly not the case once the impacts and emissions of the Chinese manufacturers were included in the assessment. "If you don't make anything, it's very easy to be carbon neutral," Professor Sheffi remarked.

Moving onto use-phase impacts in "lifecycle assessments" (LCAs), the Professor recalled how MIT had been asked by Dyson to assess



the environmental performance of its Airblade hand drying system in comparison with other hand drying methods, including paper towels, cotton towel rolls, and another electric dryer. The difficulty, he explained, was in deciding the parameters of the assessment. "To find out which one is the best for the environment, what would you analyse in order to provide an answer?" Professor Sheffi asked. "What's the definition of a dry hand? How much energy do you need to dry a hand? How many hands do you dry in a lifetime? What's the supply chain energy impact? Have you done a sensitivity analysis to define parameters?" His point was to illustrate the complexity of undertaking these analyses and comparisons. "It took only 30 people two years" to decide Dyson was the best overall performer, but not in every circumstance, the Professor noted.

Tesco also tried to do LCAs on its products, but quickly realised it would take too long and be too expensive, Yossi Sheffi said. Realising it could only manage to produce LCAs for around 125 products per year at a cost of millions of UK pounds, Tesco concluded it would take seven centuries to assess all 90,000-plus of its current products alone. Walmart, too, started down the same

road, but withdrew on realising the scale of the challenge. Despite the complexities of LCAs, Professor Sheffi said there are three primary reasons why companies should act to improve their sustainability performance.

First, enhanced eco-efficiency can reduce costs – for example by reducing energy consumption - and improve service. "For example, Staples put regulators on their trucks. They go slower and use less fuel."

Second, it can help mitigate eco-risks such as attacks by NGOs, the media, and even consumer groups, which can reduce sales and stock price. As an example, Yossi Sheffi noted that Nike was boycotted when people found out they were paying very low wages to workers in Pakistan.

Third, it can enable companies to implement eco-segmentation and hedging. Expanding on this third reason, Yossi Sheffi said that by developing an offering for the "green" market companies can gain an understanding of that market, get to know demand patterns, master the technology requirements, and identify suppliers. This can be helpful, particularly if there is potential for market changes in response to regulations or

demand shifts. He cited Clorox's "Green Works" experiment as a way to test the market for products seen as being "greener."

But there is a problem, the Professor warned as he urged companies to take a cautious approach to making changes towards sustainability: "Consumers say they want more sustainable products and processes, but they won't always pay for them." For this reason, companies should wait until consumers really are ready to pay for what they say they want before making changes. For example, in 2014 Ford was voted the best global green brand in a survey conducted by Interbrand and Deloitte. At the time, Ford had decided sustainability should be integrated into its business. Consequently, it was offering a mix of hybrids and electric vehicles. But earlier in 2018, Ford began lobbying for a relaxation in miles per gallon standards and said it intended to eliminate most cars and focus on producing trucks and SUVs, which are less fuel efficient than sedans. "Why? Ford changed because fuel has become cheap but mostly in response to consumer preference," Yossi Sheffi noted, adding that GM and Fiat-Chrysler are now also changing their product mix in response.

The conclusion is that companies will respond to their customers' demand regardless of their management's beliefs, Professor Yossi Sheffi stated.

Companies making changes to processes and products in pursuit of greater sustainability also face the challenge of convincing consumers that these changes really are delivering the gains claimed for them. The MIT Professor offered the example of used cars and the

'Akerlof Effect': if used car buyers can't distinguish between good cars and so called 'lemons' – poor quality used vehicles - they will not pay extra for a car just because the seller says it is good. Rather, they will only pay for the 'average' quality. Consequently, sellers of high-quality cars will leave the market, eroding average quality and damaging the market. In fact, what reputable sellers do to back up their claims is to offer warranties. Professor Sheffi's point was that if consumers cannot judge the level of claimed sustainability, they will not pay for sustainable products.

Different companies take different approaches to sustainability, pricing, and their offers to customers. Walmart, Yossi Sheffi said, takes the view that sustainability will be implemented where and when it lowers cost. Others will accept a lower rate of return on sustainable products. Clothing retailer, Patagonia, meanwhile, has managed to get higher prices for certain products through marketing product sustainability to a specific, receptive audience. In the US, other companies have gone down the 'benefit corporation' route to be recognized by many State governments as for-profit enterprises that also make clear their aims are

to combine profitability with positive impacts for employees, society and the environment. However, whatever companies may want to do to increase sustainability will be tempered by what Yossi Sheffi called a "limit of influence" when it comes to their suppliers. Taking the example of original equipment manufacturers (OEMs), the MIT professor noted that these companies might not know the identity of their deep tier suppliers – who might be suppliers to their suppliers' suppliers – with whom they have no direct commercial relationship. In this case, it becomes hard for the OEMs to comprehensively assess sustainability in a LCA.

Another problem facing industry, governments and society, is the potential struggle for the control or shaping of public perceptions concerning sustainability and the supply chain. As an example, Yossi Sheffi pointed to "the sticky business" of oil sands in Alberta, Canada. The extraction process involves burning large quantities of natural gas to generate steam that is injected into the ground to unlock and enable mining of the bituminous deposits. The process has a carbon footprint 10%-30% higher than other fossil-based energy

sources, uses several barrels of water per barrel of oil produced, and involves forest clearance. Environmental Defense Canada has called it, "The most destructive project on Earth." In an effort to stop oil sands exploitation, in 2010 a campaign was launched by ForestEthics demanding that any company with a supply chain involving the use of oil from oil sands fields include the impacts in their environmental footprints. In this regard, ForestEthics also named without their consent several companies, including Levi Strauss, GAP and FedEx, which, it claimed, supported the campaign. Countering this attempt to disrupt oil sands production by targeting users along the supply chain, the Alberta government pointed out that the industry was proving 30% of the province's GDP, was the top employer of indigenous people, and would generate Can\$2.5trn over 30 years. Further, it was claimed oil sands extraction was not as 'dirty' as its opponents claimed. For example, between 80%-95% of water used would be recycled, by 2010 emissions per barrel had been reduced by 26% from 1990 levels, and only 1.25% of boreal forest would be mined with up to 12m seedlings planted during land reclamation. The result was that those downstream companies named by the ForestEthics campaign found themselves in the crossfire



those supporting the industry. One Canadian remarked that if Levi Strauss, GAP and other companies didn't want to be tainted by association with Canada's oil sand industry, then perhaps they could stop selling their products and services in the country and instead purchase their oil "from regimes that provide no human rights or environmental stewardship." In its defence, Levi Strauss stated: "We do not take a position opposing or supporting any fuel or energy source from any country or geography."

For Professor Sheffi, the oil sands story is an example of how companies can become mired in the complex struggle for sustainability in an age of campaigning in which slogans such as "People vs Planet," "Planet vs Profit," and "Profit vs People" are commonplace. "What's the real deal?" he asked. It's "People vs People," he said, a struggle between those who want a clean environment, and those who want energy, jobs and affordability. When, as Professor Yossi Sheffi suggested, both sides of this argument are right, the challenge for companies and governments is to balance action and regulation against consumer wants and needs, which may differ according to their economic, social and geographical circumstances.

BRIGHTER USE OF RESOURCES: HOW ALTERNATIVE BUILDING BLOCKS LIKE CO₂ CAN BE USED IN THE PLASTICS INDUSTRY

Dr. Christoph Gürtler, Head of Catalysis and Technology Incubation, Covestro Deutschland AG

Beginning his speech, Dr. Christoph Gürtler said he intended to talk about how his company, Covestro Deutschland AG, is looking to "turn burdens into opportunities" through the use of chemistry, and more specifically about finding new uses for CO₂. The challenge, he said, is to close the carbon cycle and conserve fossil fuels by using carbon, on which the chemical industry is dependent, in the most productive way. Currently, the main source for carbon is fossil fuels, some 4%-6% of which are used for the production of plastics, Dr. Gürtler said. To date, the industry has focused on conserving carbon resources through measures such as production optimisation, lowering energy consumption, devising more sustainable products, and reprocessing and reusing raw materials. However, there has been limited reuse of waste CO_2 . Primarily a product of combustion, CO_2 is available in abundance and has the potential to be a sustainable raw material for use instead of oil.

While reusing CO₂ is technically demanding, Christoph Gürtler outlined how Covestro is now using the gas in the production of polyols, which are used to make a variety of plastics and coatings. The key has been the development of a new process by Covestro in collaboration with the CAT Catalytic Centre in Aachen, Germany, and an eight-year period of commercialisation from mini-plant to industrial scale production of 5,000 tonne/year, with a world scale plant planned. Covestro's new CO₂-polyol – cardyon[™] - is combined with isocyanate to produce polyurethanes. Dr. Gürtler said the new polyols are being used in industry standard foams and generating materials with excellent properties. The first consumer end-use is in mattresses, but the potential market is up to 3m tonne/year. "In terms of their impact on sustainability, we needed to provide proof that CO2 polyols are a good solution for polyurethanes," Dr. Gürtler explained. The new CO₂ polyol

has performance characteristics similar to conventional polyols but uses up to 20% less propylene oxide. Depending on its production process, producing 1kg of propylene oxide can generate around 3kg of CO_2 . Savings on propylene oxide hence leads to emission reduction for the new polyol. CO_2 for $\mathit{cardyon^{TM}}$ is sourced as a waste product from an adjacent ammonia plant in Dormagen.

Looking ahead, Dr. Christoph Gürtler said that the research on carbon from CO_2 is promising, offering the potential to be a platform technology with a wide range of applications, from construction and insulation to auto parts.

CONTAINER SHIPPING'S CONTRIBUTION TO SUSTAINABILITY

Jörg Erdmann, Senior Director of Sustainability Management, Hapag-Lloyd

"Maritime shipping is the most carbon-efficient method of transportation," Hapag-Lloyd's Jörg Erdmann reminded his audience. Overall, transportation contributes about a third of global CO_2 generation, but maritime shipping is responsible



for just 2%-3%. Offering comparisons, Mr. Erdmann noted that while shipping generates an average $2.3g\ CO_2$ per tonne-km, rail generates $35g\ CO_2$ per tonne-km, trucking $110g\ CO_2$ per tonne-km, and air transport $665g\ CO_2$ per tonne-km.

However, the shipping industry is not content to stand still and is looking to improve its environmental performance by reducing ship emissions. From 1 January 2020, the International Maritime Organisation (IMO) will begin enforcing a 0.5% global sulphur cap on fuel content, down from the current 3.5% limit.

In order to comply with these new regulations, Jörg Erdmann said the industry has been pursuing several options. These include switching to LNG fuels, using compliant fuels - an option complicated by the need for fuel suppliers to be able to supply compliant formulations to the right places at the right times - or installing scrubbers.

LNG offers significantly lower CO_2 emissions, but its use entails high upfront capital expenditure, and bunkering logistics and infrastructure require investment and expansion. Compliant fuels require lower investment to ensure segregation of fuels, but they are expected to be priced at a premium over high sulphur fuel oil (HSFO). Installing scrubber technology will allow the continued use of HSFO, but the technology is expensive and onboard installation can pose significant challenges not least to a ship's stability. Jörg Erdmann said Hapag-Lloyd is currently evaluating all options, although it already has 17 LNG-ready vessels in its fleet.

The company, he added, is reviewing economics and feasibility on a case-by-case basis and estimates the overall additional cost will be around \$1bn/year.

The IMO's low sulphur regulation is part of the organisation's strategy to reduce the industry's greenhouse gas emissions in line with global efforts to limit climate change to 2°C. So, by 2030 the IMO is aiming to reduce shipping's CO₂ emissions to 40% of 2008 output, and to 50% by 2050. Longer-term, the 2100 aim is a carbon free economy. In the short-term to 2023, the IMO is encouraging improvements in a range of areas such as energy efficient design and speed optimization. Mediumterm measures - from 2023-2030 - will focus on low-carbon fuels backed up by market-based efforts, while from 2030 onwards the priority will be on achieving zero-carbon fuels.



For its part, Hapag-Lloyd has been actively reducing the ${\it CO}_2$ emissions from its fleet, which are forecast by 2020 to be down 59% from 2006 levels, Mr. Erdmann said.

In addition, the company is promoting and collaborating on customer initiatives to cut their CO_2 transport emissions. It is also playing an active part in co-operative efforts such as the Trident Alliance of shipowners and operators that promotes robust and transparent enforcement of the new low-sulphur rules and regulatory compliance, the World Shipping Council, and the Clean Cargo Working Group.

There are a variety of short-term measures that Hapag-Lloyd is implementing, both onshore and offshore, to improve its sustainability performance, Jörg Erdmann continued. These include ship speed and operations optimization, energy management plans, crew training on efficient fuel use, retrofitting vessels for

onshore power supply, new optimized bow and propeller designs, low friction coatings to cut water resistance, and energy efficient refrigerated containers. Hapag-Lloyd has also set up a Fleet Support Centre to optimize workflows on sea and land. Concluding, Jörg Erdmann said that while the IMO strategy is ambitious, with key stakeholder involvement it can succeed. In terms of technical developments, the energy and chemical sectors can contribute to innovations in fuel cell systems and batteries, or alternative fuels such as biogas, hydrogen and methanol.

In the operational area, the industry can pursue measures such as optimized routing, slow steaming and in-time berthing upon arrival. Looking more broadly, Jörg Erdmann said there is a need for a level global regulatory playing field with worldwide enforcement and standards, and also a need for a better commercial understanding between economic and environmental goals.



QUESTION & ANSWER SESSION:

Following their presentations, the three speakers – MIT's Prof. Yossi Sheffi, Covestro's Dr. Christoph Gürtler, and Hapag-Lloyd's Jörg Erdmann - took part in a Q&A session with moderator Nadine Dereza and the audience.

Q: Are you seeing price-related pushbacks for your sustainability efforts in relation the higher costs of low sulphur fuel? Jörg Erdmann: "Well, the increase in price is significant, experts talk about \$60bn extra a year annual cost. For a company like ours, we estimate about \$1bn a year in extra fuel costs. But the customer is still choosing us, because it's a greener way, and hopefully they will pay for it. But yes, there is and there will be pushback." However, Jörg Erdmann suggested the key to solving this issue is through partnerships between suppliers and customers to build understanding of the issues, the costs and the value of sharing the burden of sustainability.

Q: How can the technical challenges to sustainability be overcome?

Christoph Gürtler: "Through time, money and perseverance!" Recounting, how it had taken Covestro eight years to develop the new CO₂ polyols, Dr. Gürtler said the process demonstrated the company's determination and ability to produce new chemicals that provide a better balance of sustainability. However, he stressed that Covestro's technological development efforts are not driven by "pure altruism," but also have a good business case.

Q: How important are regulatory frameworks for shipping and what are the enforcement issues?

Jörg Erdmann: They are very important in terms of having a level playing field for the industry. For example, IMO's Marpol (Marine Pollution) Convention has to be adopted and enforced by IMO Member States. However, rules and regulations are much easier to enforce in policeable coastal waters than on the high seas. To an extent, technology can monitor compliance, particularly among the biggest players, but others may not follow the rules.

Q: Yossi Sheffi was asked whether he thought electric cars – being pushed by governments and some consumers - made sense in terms of cost and sustainability?

"The push to electric cars makes sense. It will reduce overall CO₂ emissions, particularly if we can get over our hangup about nuclear power. But if we don't it's a problem. We also have to account for impact of manufacturing the cars, the parts, the batteries: that is not a small thing." Using hybrid cars as an example, Professor Sheffi said in pre-Fukushima Japan, where nuclear power was still a major source of electricity, an owner would need to drive 25-30,000km/year to gain a sustainability advantage over a conventional car. However, in India, where coal is the main source for electricity generation, owners would need to drive over 250,000km/year.

Q: Christoph Gürtler mentioned Covestro is planning a world-scale CO, polyols plant. What is the timeline for such a plant? Could CO, replace fossil fuels? Christoph Gürtler: "The timeline for a world-scale plant is 5-6 years. You have to ask: Is the current plant safe, reliable, and do the customers like and want the product? Then you start planning and building the new plant. And, no, CO₂ cannot replace fossil fuels." However, he said that catalysis offers great opportunities for new combinations of bio-based and fossil-based molecules for new and replacement applications. The drivers will be a mixture of chemistry, business opportunities and regulations.

Q: Christoph Gürtler was then asked about the role and the problems of collaboration in developing new materials and processes.

Christoph Gürtler: Collaboration is and will remain very important, but there will always be questions concerning intellectual property and competition rules, he said. But Christoph Gürtler also noted that collaboration along the supply chain, with suppliers and customers, is a key element in the development of new processes and materials.

Q: How is technology – such as digitisation, blockchain, and artificial intelligence - changing business?

Jörg Erdmann: Digitisation is happening very fast in the shipping industry. Blockchain will be very important for facilitating communication

along the supply chain, and digitisation is enabling optimized routing, container tracking, etc., and helping sustainability.

Q: Could 3D printing be a gamechanger for industry?

Yossi Sheffi: "Not yet. But it could be. Right now, 3D printing is used mainly for one-off items." He offered the example of hip replacement surgery where customised replacements are now made to fit individual patients via MRI scanning and 3D printing. GE is using 3D printing to make 40,000 engine parts per year. "It could be that in future instead of moving products all over the world that we move raw materials and then certain items are 3D printed locally. But I can't see a time when say a toaster is 3D printed at home."

Q: Even though both sides of the sustainability argument – for example, environment versus human wants and needs – have their merits, is there a time when it is right to "balance green"?

Yossi Sheffi: "The answer is: when you live in Europe, you may think so. But when two thirds of humanity live in places where people make \$2-5/day or even \$2-5/week, and electricity is still a luxury, then they may

not want to balance green. By the way, your governments - in Europe and the USA don't want to balance green, either, because they protect the automotive industries and reduce [environmental] restrictions to help their industries." If people can afford to pay, then the green balance will win. But Yossi Sheffi also questioned the commitment of those who say they want to be greener, but then choose superfast single-item deliveries from companies like Amazon and pay a premium to secure them at an additional cost to both customer and the environment. "If something really bad happened, such as New York, Miami or Shanghai getting flooded, then people might change their habits. But it's still not going to happen in Africa or India or where people cannot afford it." In the end, it will be the consumer that drives change if consumers change their habits.

Q: Given that a box of bananas has a footprint of 7kg of CO₂ and requires about 550 litres of water, should we refrain from eating bananas?

Yossi Sheffi: The thing about the banana is that it is a simple product that comes in its own packaging. But the reason to look at the banana as an example is because

even with such a simple product both the lifecycle assessment and the supply chain is still complex. However, Yossi Sheffi said: "Eat as much as you want!"

Q: What final points would the panel like the audience to think about or take away?

Jörg Erdmann: Shipping in the globalized world is a necessity, and a driver for growth and exchange of goods. But we will find solutions to improve the sector's sustainability.

Christoph Gürtler: "I think the industry will be increasingly pressurised and sensitized in terms of climate and environmental footprint. We need to use our creativity and adapt to whatever kind of regulations are going to be put in place."

Yossi Sheffi: "I want to make two points. The first point is that a 2°C rise in global temperature is going to happen despite the warnings of the IPCC and the efforts of some people, some companies, and some countries. Why? What is the number one objective of every CEO and for GDP? Growth! So, CO₂ emissions will keep going up. We'll have to keep using petrochemicals, and we'll have to move them around. In order to stop CO₂ increasing you can do two things: First option is to either stop economic growth or stop population growth. Second option is, that to make a real difference, we will need technological cooperation on a global scale – like a global Manhattan Project – to introduce mitigations such as carbon capture and storage."





Challenges and Opportunities in solving the climate change challenge

Professor Steven Chu, William R. Kenan, Jr., Professor of Physics and Professor of Molecular & Cellular Physiology in the Medical School at Stanford University, U.S. Secretary of Energy (2009-2013) and co-recipient of the 1997 Nobel Prize in Physics

In the first part of his speech to the delegates, Professor Steven Chu painted a stark picture of the scale and impacts of climate change facing our world today and in the future. Presenting a variety of data that tracked the increases in greenhouse gas emissions and average annual global temperature, Professor Chu cast doubt on the world's ability to restrict climate change to the UN's target of a 2°C rise. But striking a more positive note, the Nobel Prize-winning physicist moved on to suggest technological innovations in renewable energy options, including new electrochemistry developments,

that could transform both the global energy and climate outlooks. To make these changes a reality, however, Steven Chu urged the scientific community to engage with government in an effort to shape and influence energy and climate change policies.

Since 1970, Steven Chu began, the global average temperature has increased by 0.9°C and the consequences are being seen in a range of developments, from accelerated loss of Antarctic ice, to increases in forest fires, heat waves, water shortages, crop failures, storms and heavy rainfall. Furthermore, potential rises in sea levels could create tens of millions of "climate refugees" in the coming years.

Turning to emission scenarios, Stanford Professor Chu said that meeting the UN's climate change target would require negative "greenhouse gas" (GHG) emissions by 2080. Given increased global demand for heat, power and food, he thought such an outcome unlikely. While noting that the world acted in the face of the challenges of acid rain, Steven Chu pointed out that the turnaround had taken around 10-15 years of clean up. However, with regard to GHG $-\,^3\!\!\!\!/$ of which had been generated in the past 65 years - and CO $_2$ in particular, the Stanford Professor suggested that even if humangenerated CO $_2$ emissions to atmosphere stop by 2150, half the CO $_2$ emitted would still be circulating for 10,000 years.

Having delivered the bad news, Steven Chu offered a more positive outlook with regard to sustainable energy generation. At present, the largest offshore wind turbines are 6-7MW, but by 2023 a new generation of 15MW turbines will be installed with wingspans comparable to the biggest passenger aircraft. Meanwhile solar power continues to advance with, for example, US generating costs



dropping steeply from around \$200/MWH in 2006 to \$30/MWH today.

Consequently, wind and solar power costs have moved closer to or even achieved parity with fossil fuels such as natural gas. At the world's best sites, renewable energy costs are below 2.5¢/KWH and will likely fall to 2¢/KWH or below by 2030. However, Steven Chu noted that the full cost of renewable energy includes backup generation capacity, energy storage, and an enhanced transmission and distribution system. Looking around the world, Steven Chu said China is the leader in wind and solar and high voltage transmission systems. An issue for both wind and solar power is storage, but Professor Chu said progress is being made in batteries and other storage options.

China is currently the global leader in hydroelectric power generation and their 5-year plan ending in 2020, will have 380GW installed generating capacity. In a 2015 IEA report, China had 280GW of capacity, followed by Brazil with 89GW, the US with 79 GW, and Canada with 78GW trail some way behind. In terms of pumped storage power plant capacity – when water is pumped backed into reservoirs at times of low power demand – by 2020 China will pull ahead with more than 40GW by 2020, and there are plans that project that China may have 90GW by 2030.

Steven Chu also mentioned that machine learning is increasingly being applied to manage more efficiently increasingly complex power transmission and distribution systems. Using techniques similar to those employed in the Go game playing system and Google translation system, machine learning can, for example, enable better understanding of energy use patterns or improve weather predictions, and improve flexibility and response in the power system.

Another positive trend is the increase in electric vehicles, Steven Chu said. Between

2015 and 2016, he noted, sales forecasts for electric vehicles had soared by 500%. China is targeting 11% of car sales to be electric by 2020, and their estimates suggest there will be 70m electric vehicles on the road. What's more, the Professor noted, by 2020 the manufacturing cost of lithium ion batteries for cars are forecast to fall to just 10% of 2006 costs, which began at around \$1,500/KWH.

As an example of how environmental pressures can bring about rapid technological change, the Professor looked back to New York City in the late 19th and early 20th centuries. In 1880, there were 160,000 horses in Manhattan, generating 4m lb "horse poop" and 40,000 gallons of urine each day. And whereas on Easter morning 1900 5th Avenue was jammed with horse-drawn carriages, by 1913 horses had mainly disappeared to be replaced by automobiles. Of course, the transition from horse to automobile required an oil-gasoline supply chain, paved roads, and other infrastructure.



require a lithium metal anode where dendritic growth that occurs at high charging rates is supressed.

Steven Chu also believes that clean electricity available at 2¢/kW will open up exciting opportunities in electrochemistry, from energy generation to storage and recycling of combustion products including the transformation – via a mixture of thermochemical, electrochemical, photochemical and biochemical processes – of CO₂ and water into hydrogen, carbon monoxide and oxygen for energy and industrial use.

Professor Steven Chu mentioned that one of his current co-research projects is the development of an artificial alveolus, which mimics the way alveoli in human lungs exchange gas, to harvest hydrogen and oxygen from electrolyzed water.

Although Professor Chu does not expect the world to meet the UN's climate change targets, he remains optimistic that science can solve the climate and energy challenges the world is facing. He believes the keys are focusing research on clean energy and energy efficiency, and mitigating CO₂ emissions.

CLOSING REMARKS BY EPCA PRESIDENT, MARC SCHULLER

Closing the conference, EPCA President Marc Schuller said that having benefited from growth taking the industry into new markets in new locations with new customers, the petrochemicals sector now needs to look ahead and focus on how it can support the transformation to a global low-carbon economy. Having thanked speakers, delegates, and the EPCA team for contributing to a very successful meeting, Marc Schuller announced that the 2019 Annual Meeting will be held in Berlin from 6th-9th October. "The best way for us to survive and prosper is to keep a long-term view," he concluded.

General disclaimer: The content of this report of the 52^{nd} Annual Meeting in Vienna (Austria) merely intends to summarize the presentations given by the speakers at the event and does not necessarily reflect the position of EPCA.

Today, however, we face a new challenge brought about by air pollution from power generation, transportation and industrial production. Steven Chu pointed out that while the current scientific consensus is that particulate matter above 2.5 µm/m³ can be deadly, the WHO guideline is currently 10 µg/m³, and the average air quality in Beijing in 2016 was around 76 µg/m³. Meanwhile, estimates suggest 4.5 million deaths per year are due to air pollution causing illness such as coronary disease, stroke, lung cancer, and chronic obstructive pulmonary disease.

Given the health issues related to current air quality, the drive for more efficient battery systems will have significant impact on the growth of electric vehicles. Professor Chu noted that he and a colleague, Professor Yi Cui, from the materials science department at Stanford are looking to develop a new generation of lithium metal batteries that could achieve energy density and charging rates four times higher than the levels of current lithium ion batteries. This would













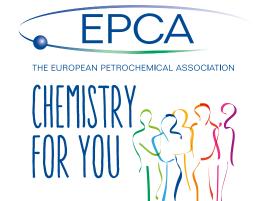








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