Recognised as a UK-Brazil Year of Science and Innovation Event

Mitigating Issues of Future Wastes: Enhancing Resource Productivity in Emerging Technologies

Environment, Sustainability and Energy Division - Event Report

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On 5th September 2018, our Environment Sustainability and Energy Division (ESED) held an international scientific meeting at Burlington House, London looking at how the chemical sciences can develop solutions to the scientific and policy challenges to mitigate the issues of waste and resource efficiency for emerging technologies.

Matthew Lloyd Davies and Rhys Charles (Swansea University) and Chris Ennis (Teesside University) from ESED Council put together a comprehensive and diverse science-policy programme for the day. This highlighted the enormous potential value that is currently trapped in electronic wastes and how the chemical sciences can bring solutions to extract the value of critical raw materials (CRMs) back into a circular economy facilitated by appropriate innovation. It also served to introduce the audience to ongoing R&D for emerging technologies and the ambitions of major players in electrification of transport and decarbonisation of the grid. This identified key emerging technologies for the future coupled with the resource efficiency challenges, which need to be addressed for these technologies in order to avoid contributing to the growing global waste electrical and electronic equipment (WEEE) problem. The introduction of new technologies to the market without proper lifecycle optimisation or eco-design and resource efficiency measures developed at an early stage will not result in the desired enhanced resource efficiency future. The event was very well attended by a range of different stakeholders including; academics, industrial partners, NGOs, regulators and innovators. This resulted in an excellent diversity of presentations as well as some healthy debate when deciding how we as chemists can contribute to tackling these new challenges.

Matthew Davies; Rhys Charles engaging with RSC Policy and Evidence Manager Tanya Sheridan; Chris Ennis.

Matthew Davies opened the proceedings by introducing the concept of lifecycle optimisation for renewables through collaborative Research and Innovation to optimise different parts of product lifecycles with identified partners with appropriate knowledge and skills. The example used was that of printable photovoltaics and the strategy used in the newly funded ACceleration of Circular Economy for Printable Photovoltaics Through Eco-Design (ACCEPTED) project (Swansea University). The ongoing international work in Swansea by the SPECIFIC IKC to develop buildings as power stations, as well as the Sunrise project which aims to develop off-grid PV solutions for rural India were also outlined.

Rhys Charles then introduced the UK-Brazil Year of Science and Innovation, and welcomed the delegates from Brazil and the Brazilian Embassy. This initiative celebrates the considerable scientific collaboration between the United Kingdom and Brazil. It also created an opportunity for scientists, entrepreneurs and other interested parties to discuss how to work together on global challenges. The meeting enabled the sharing of insights to help address domestic WEEE issues in both geographies.

From left to right: Margaret Bates, Alberto da Rocha Neto, Sebastião Eleutério Filho, Tanya Sheridan (RSC), Juliana Bertazzo (Brazilian Embassy in the UK).

Rhys Charles (Swansea University/RSC ESED council) and Margaret Bates (University of Northampton/CIWM) met with visiting Brazilian delegates Sebastião Eleutério (Centre for Information Technology Renato Archer) and Alberto da Rocha Neto (Ministry of Environment) at DEFRA the day before to discuss issues of mutual interest. These included current best practice and recent developments in legislation, industry and research, which supports management of waste electrical

and electronic equipment (WEEE) and progress towards superior environmental, resource efficiency, social and economic outcomes in the future. The Brazilian delegation, accompanied by members of Defra and the Environment Agency and our ESED members also visited a recycling facility.

From left to right: Sebastião Eleutério Filho, Callum Harris (Defra), Alan Owers (Environment Agency), Margaret Bates, Rhys Charles and Alberto da Rocha Neto.

Rhys then went on to chair the morning session of talks, designed to give context and background to further discussions throughout the day. The first technical talk of the day was delivered by Margaret Bates (University of Northampton), who emphasised that e-waste is a huge and increasing issue to be addressed not just nationally, but globally. She raised several different interesting factors, with plenty of links to consumer choices and education about how to deal with waste and recycling. Consumers perceive recycled materials as “cheaper and potentially poorer quality”. They also have a misguided perception that recycling is the most environmental friendly option. However, in most cases recycling is not the best option and it can be very energy intensive and resource inefficient. Greater environmental, social and economic outcomes are derived from reuse and other options representing the ‘tighter’ loops of the circular economy than recycling. Extending a products life cycle and reusing it is much more important, but again public perception and consumer choices play a large part. The vast majority of us prioritise having the latest phones and gadgets over these sustainability and waste issues. When it comes to the UK a lot of e-waste is actually recycled here, with material fractions generated exported (particularly those containing CRMs) however the loop needs to be closed so that materials are reused in the UK too. This highlights the necessity to develop domestic materials recovery infrastructure, as well as innovation that generates materials from WEEE as raw materials for UK manufacturing. The amount of reuse in the UK is surprising large but very difficult to measure on a national level (e.g. accounting for “hand me downs”). Whilst this was positive, we could be doing

so much better. An innovative example of this was using e-wastes to create resins for 3D printers. As well as identifying issues she also offered some solutions, these included putting more of an emphasis on extending the lifetime of products, noting that a durability standard/legislation would encourage this. There is currently a lot of legislation around waste, however this is often poorly enforced, especially in countries outside the UK that receive and process waste from other countries, including the UK. Perhaps the most crucial factor is the implementation of an appropriate individual producer responsibility system of compliance, in which compliance is charged at a sliding scale based on the environmental performance of your product at EoL (End of Life).

The second talk was delivered by Ian Forbes (Northumbria University) who discussed the use of solar power in Africa. The main global population growth for the future is likely to be in Africa, which will put a huge strain on energy demand. The climatic and weather conditions in most of Africa make solar power a great option to solve this energy demand. Solar photovoltaics (PV) are good option as they are the most widely applicable technology. Crystalline silicon is the most widely used and accounts for more than 97% of use, thin films show promise but currently have much lower market share. When we talk about countries being environmentally friendly China can often get a bad press with poor air quality and construction of new coal power plants regularly cited, however they are leading the way in PV installation and energy generation. Although solar looks like a great option, based on our current resources we would not have enough raw materials to produce the number of PV installations required to meet the energy demand. Therefore, new technologies, advances, alternatives are also required.

Allan Walton (University of Birmingham) presented some exciting options available for recycling of magnetic material from cars for which current methods using shredding are not effective. By using hydrogen his group were able break down NIB (neodymium) magnets in hard drives and demagnetise them so they can be effectively retrieved. The resultant material was a powder that could be easily separated from the other material by using a piece of kit built from a recycled washing machine drum which tumbles the drives liberating the powder which falls through perforations in the drum for collection. This easily separated the powdered former magnets so that they could be reprocessed and used to create a wide range of different products. This technology could equally be applied to NIB magnets of wind turbines, or those used in electric motors of electric vehicles.

In the first talk of the day we learnt about how consumer choices influenced the recycling and reuse of WEEE. Norah Lewis from Waste and Resources Action Programme (WRAP) provided a detailed insight into these problems by showing the success and issues encountered with their recent pan-European EULife funded Critical Raw Material Recovery (CRM Recovery) project. WRAP recently performed collection trials in collaboration with John Lewis and the British Heart Foundation in the UK, where they asked members of the public to donate small electrical items for reuse. They identified a large issue with data security. Many members of the public failed to understand how to effectively protect their data, whereas many more of us also hoard these small electrical items due to security concerns, not knowing where to take them. It was quite surprising and comical to see how many of us

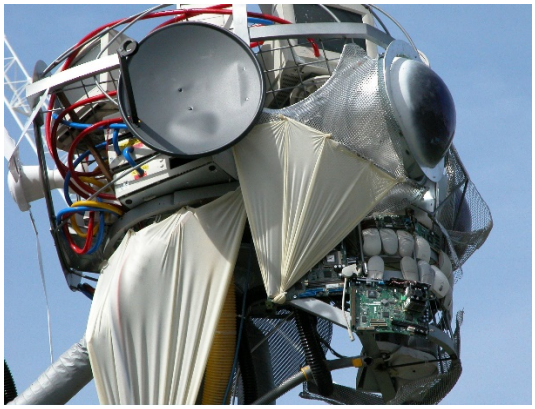
present at the conference raised our hands when we were asked if we had an old phone sitting in a draw somewhere at home.

Alan Walton, Norah Lewis, Ian Forbes; Alan showing us how to chemically destroy a hard disk

There is so much potential for the reuse of these items however we as the general public are not typically proactive at doing anything about it. The positives of WRAPs research identified that there are ways to combat this. By using trusted brands and charities they found that this helped to offset the data protection security concerns. It also meant that more items were received in a good condition making reuse more viable, along with obtaining important sub components through dismantling. Another key outcome from the trials was the determination that in order to really mitigate materials criticality, design of new products and their lifecycles from the outset must take place with a firm understanding of the value chain and adoption of systems thinking. It was also a firm conclusion of the project that to drive greater recovery and retention of CRMs in WEEE, CRM recovery must somehow be integrated into legislation.

Mark Dowling of Giraffe Innovation Ltd. presented during the last slot before the lunch break and again highlighted a number of issues that were linked to consumer demand. He showed us the 'WEEE man' which is an artistic representation of the amount of electrical waste that one person will produce in their lifetime, assuming we carry on discarding items at the current rate. Mark said, "we estimate this to be around three tonnes for the UK and similar in Europe". He highlighted the difference between tablets and laptops compared to the more traditional PCs. PCs are designed for reuse and upgrade as components can easily be replaced and transferred. This cannot be done to the same extent in tablets/laptops. He commented that the current lifecycle is too short for many electrical products and there was a decrease in ease of "fixability" of many products. He introduced the concept of ecodesign principals and showed a number of examples, including cash machines and washing machines, where he has worked to design more effective products with longer life cycles. Relatively simple yet eloquent solutions were put forward for a variety of other products such as paper pallets for lightweight products to reduce CO_2 from shipping, reducing packaging size and using reusable materials. He raised a number of current issues and proposed sensible solutions for the future, he

mentioned that we should strive to use less material, make materials easier to recover, make it easier/cost effective to repair products, improve data security issues for electronic devices and incentivise WEEE returns.



WEEEMAN: © Giraffe Innovation Ltd.

Javier Perez-Ramirez (ETH, Zurich), who was presented the ESED Sustainable Energy Award by David Phillips, gave an amazing talk highlighting the role of catalysis in achieving resource efficiency in chemicals manufacturing. This was an extremely interesting talk giving new insight into cutting edge elucidation of catalytic processes, and how the amounts of many of the critical raw materials used in catalysts can be reduced by functionalising the surfaces of inexpensive support materials. This is particularly important for PGM (platinum-group metals) containing catalysts.

Javier Perez-Ramirez (left) being presented with the ESED Sustainable Energy Award by David Phillips.

Colin Heron CBE (Zero Carbon Futures) opened his presentation with one of the more controversial comments of the day as he proceeded to point the finger at chemists as the reason why electric vehicles are not as successful as they should be. This could be considered a somewhat bold statement to make to a room full of chemists at the home of Chemistry, but it was one that was well meant and backed up with logic and evidence. He mentioned that there was currently a perfect storm for electric vehicles to take over the market, with advantages such as; lower emissions, shareholder pressure, and new technologies. So why haven't they? The press and a lot of car manufacturers are saying they will

make loads of electric vehicles, the UK government are also releasing more funds for the technology. However, the staunch reality is that the number of electric vehicles currently on the road are much lower than where they should be to meet these targets. He noted a couple of reasons for this and chemistry has an important role to play in each of them. Appropriate infrastructure for charging is identified as an issue by some people, but only 4% of this infrastructure is currently utilised so this doesn't appear to be a major problem. Something more concerning is the very different charge rates for different electric vehicles, models and manufacturers. This has a huge knock on for charging stations as plugging in for the same amount of time will result in different amount of charge being supplied to different cars. Making the cost of charging fair and equitable is a challenge. The main limiting factor in Colin's opinion is that manufacturers are currently sitting on the fence and are not committing to which type of battery technology to use in their cars. There are many limitations with the current Li-ion batteries (such as there is not currently enough Li available on the planet to produce as many cars as we are projecting). There are competing solid state batteries under development, however the industry is still waiting for chemists to make a commercially viable battery. Colin indicated that there is also a severe skills gap to support the development of the new battery systems for cars in the UK, and charging infrastructure, as well as expertise in terms of emergency services etc. This is something that he is keen to discuss and look at further addressing with the help of the chemistry community.

The next presentation was given by Sara Walker who talked about energy systems integration (the operation and planning of energy systems). She talked about trying to employ a whole systems approach to manage the different energy networks more effectively. This would lead to lower costs, lower carbon and more resilient networks, all positive outcomes. One of the main barriers to this approach is that the electricity and gas networks are not effectively coupled due to regulators creating boundaries through different types of regulation. Sara showed an example of a promising pilot study that is currently underway to attempt to fix some of the existing barriers so that different energy systems can work more effectively together.

Stuart Coles (University of Warwick) provided more information to back up some of the data shown by Colin Heron at the start of the session. He mentioned that there were 0.5 million electric vehicles in 2013 and we were up to 3 million electric vehicles worldwide in 2017. Rather than focusing on which battery to use he raised an important point about the batteries currently in use. There is a huge potential recycling problem due to Li-ion batteries in old cars. The battery lifespan is approximately 8 to 10 years, so we are now coming to a point where these need to be recovered and we might not have the understanding and infrastructure to do this effectively. Batteries contain a lot of different components that pose a challenge for reclamation and recycling. He mentioned the need to investigate ways for a more circular economy for batteries. Rather than recycle are there ways that we can directly reuse some of these batteries in cars again or for other uses such as energy storage in 3rd world solar farms?

The final technical talk of the day was delivered by Patrick Schroeder (Institute of Development Studies) who discussed a circular economy for current renewable energy sources. He showed how

lead acid batteries are currently a big problem in developing countries as unsafe recycling practices can lead to adverse health effects. There were pictures of workers physically smashing apart batteries and picking out components by hand. He mentioned that it is very difficult to trace what happens to batteries after they have been reused in developing countries, especially what measures are in place for end of life management. He also mentioned some worrying points if the Li-ion batteries get sent to developing areas for reuse. Whilst this has clear short term benefits we must consider what happens after the end of that use. Current technologies for recycling lead acid batteries (cutting open) will result in explosions so we need to share technology too. We should take more responsibility for what happens at the end of a products life rather than shifting the problem elsewhere. He also provided examples of similar issues in other green energy industries, PV solar panels and wind turbine blades are now a recycling problem in China. These are examples of where we have thought on too short a timescale and created a future problem. The amount of these waste materials is only going to increase as demand for green energy is growing. To help address some of these problems he presented some research on using alternative materials for wind turbine blade manufacture (bamboo) which can be composted. The take home message from this presentation was that for any product we need to take more responsibility for what happens at the end of life.

Following the technical presentations, delegates participated in a discussion session, chaired by Chris Ennis, on the direction of future research needed to address resource efficiency challenges and the role chemistry could play in finding solutions. The output of these discussions will be developed further as part of the RSC's work on waste and resources policy in 2019.

In summary, the day was full of exciting science that is aiming to provide solutions for processing electronic wastes to recover CRMs and also in generating energy from waste. Technical solutions from the chemicals sciences, sound policies and a change in behaviour from consumers, all need to evolve and come together via effective collaborations, and new government policies, nationally and internationally, to ensure that we retain the value of our critical raw materials from emerging electronic wastes.