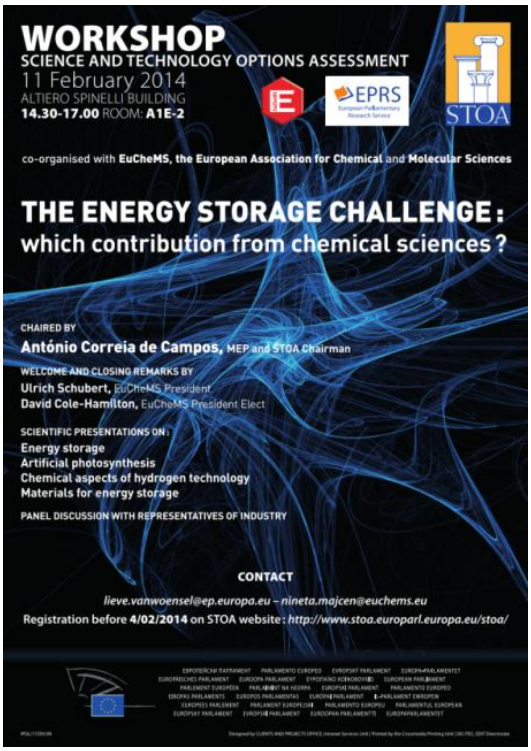
Science and Technology Options Assessment

STOA Workshop
co-organised with the European Association for Chemical and Molecular Sciences (EuCheMS)
European Parliament, Brussels 11 February 2014

The energy storage challenge: which contribution from chemical sciences?

Participants' booklet



EPRS European Parliamentary Research Service

EUROPEAN PARLIAMENT

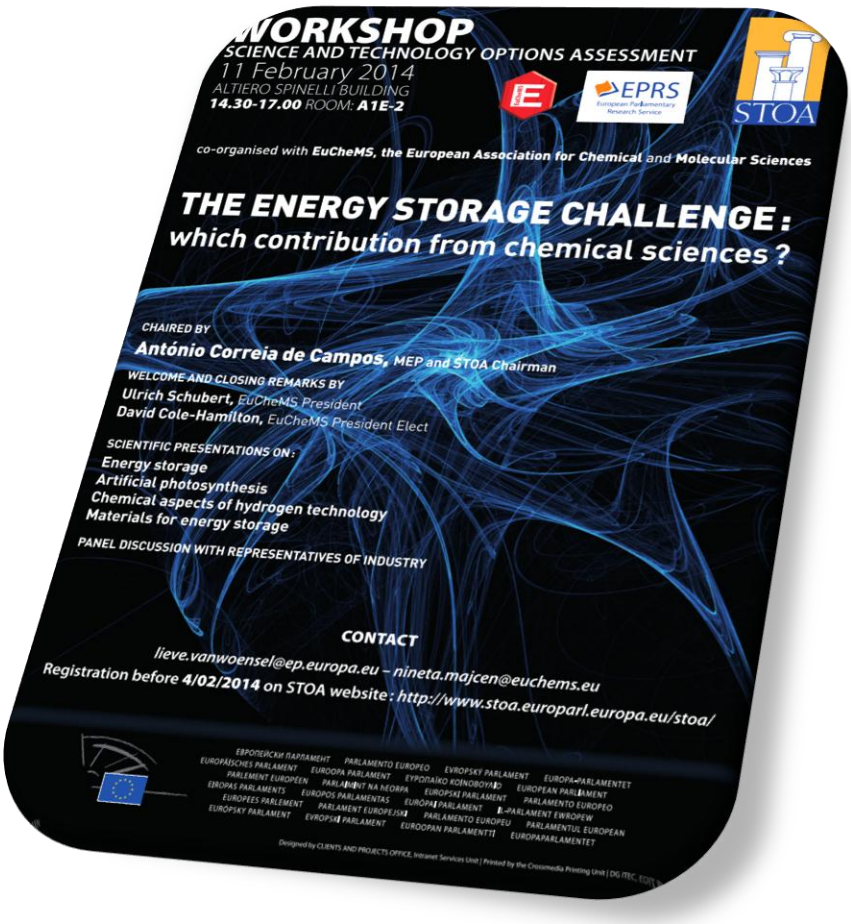
Prepared by Lieve Van Woensel
STOA Research Administrator
with the assistance of Stephen O'Sullivan and Filippo Bramati,
STOA Trainees

Lieve.vanwoensel@ep.europa.eu

http://www.europarl.europa.eu/stoa/cms/home/events/workshops/storage

STOA appreciates your questions
for the panel discussion via Twitter using

#STOA



Programme

STOA Workshop
Co-organised with the European Association for Chemical and Molecular Sciences (EuCheMS)

The energy storage challenge: which contribution from chemical sciences?

Opening session

Welcome by António Correia de Campos, STOA Chairman, MEP

Welcome by Ulrich Schubert, EuCheMS President

Keynote speech: '**Chemical Sciences for Energy storage: a societal challenge',** *Serdar Sariciftci, Johannes Kepler Universität (JKU) Linz.*

Session 1

Artificial photosynthesis, *Prof. Gabriele Centi, Univ. of Messina*

Chemical aspects of hydrogen technology, *Professor Neil Champness, University of Nottingham*

Energy Storage, *Prof. Dr. Ferdi Schüth, Max-Planck-Institut*

Materials for energy storage, *Prof. Kristina Edstrom* **-** *University Uppsala*

Session 2

Panel discussion - Q&A session

All speakers and a representative of chemical industry: Fabrice Stassin (Umicore)

Closing remarks

David Cole-Hamilton, EuCheMS President Elect

António Correia de Campos, STOA Chair

STOA: 27 years of scientific advice for evidence-based European policy-making

STOA stands for Science and Technology Options Assessment. It is an official body of the European Parliament, launched 27 years ago, in 1987. STOA's task is to carry out independent assessments of the impact of new technologies and to identify long-term, strategic policy options useful to the Parliament's committees in their policy-making role.

STOA's work is governed by the STOA Panel, which consists of 15 MEPs: the Vice-President of the European Parliament responsible for STOA and members appointed by six different parliamentary committees.

STOA's activities mainly concentrate on strategic topics and societal challenges such as:

- Future energy and transport scenarios,
- Sustainable society, covering for instance food security and sustainable agriculture,
- Developments in Information and Communication Technologies, including ethical implications of social media and e-democracy,
- Future prospects in health and life improvements.

Scientific evidence and advice are often needed to underpin decision-making, as developments in science and technology have potential implications across many policy areas. STOA's mission is to ensure that European policy-making is supported by sound scientific evidence. When a democratically elected MEP considers that it would be helpful in his/her policy-making role to seek out expert, independent information of the different scientific or technological options in a certain policy sector, STOA is at his/her disposal.

STOA fulfils its mission primarily by carrying out – in a neutral and independent way – science-based projects. While undertaking these projects, STOA will always assess the widest possible range of options to support policy decisions. Examples of STOA projects show a wide range of research and policy areas: nano-safety, e-Democracy, bio-engineering, smart energy grids and sustainable agriculture.

An average STOA project investigates existing and emerging technology options in a specific policy area, and assesses the impacts of these options. This ensures that MEPs are provided with state-of-the-art knowledge to reflect upon when carrying out their policy-making tasks. Of course, the Members also take into account other factors, such as their individual political and ethical values, when they make up their minds.

The projects are carried out in partnership with external experts. These can be research institutes, universities, laboratories, consultancies or individual researchers. All STOA studies are available for everyone who is interested – they can be downloaded from the STOA website. All events organised by STOA are open to the general public.

These STOA events aim to bridge the gap between the scientific community and policy-makers. This is done by stimulating dialogue and discussion forums, especially in the form of workshops. STOA has been organising an increasing number of workshops on a wide range of topics of political interest.

European Association for Chemical and Molecular Sciences

EuCheMS is the umbrella organization of the Chemical Societies in geographical Europe, embracing 42 Member Societies in 32 countries and representing about 156.000 individuals (including 31.000 students). As such, EuCheMS is the voice for chemical and molecular sciences in Europe. Through its activities it acts at the European level, both within the European Union and worldwide.

The activities of EuCheMS, as a supranational organization, are focussed on

- increasing the visibility of chemistry at the European level by speaking with a single voice,
- creating a European "corporate identity" among the Chemical Societies,
- presenting chemistry as an essential and indispensable provider of solutions for global challenges to European and international institutions and other relevant stakeholders.

The work of EuCheMS rests on three pillars, which complement national activities of the Member Societies on a transnational level:

- networking
- European chemistry congresses and
- policy related activities

EuCheMS Divisions, Working Parties and the European Young Chemists' Network (EYCN) have developed strong thematic networks in scientific areas as well as on general issues related to chemistry.

This year, the 5th EuCheMS Chemistry Congress, which is a unique place for all chemists to meet, will take place 31 August – 4 September in Istanbul.

Policy activities promote chemistry at a European level. EuCheMS statements are considered impartial since EuCheMS is not defending national or economic interests.

The chemical and molecular sciences have been fundamental to current economic and social achievements in Europe. They will continue to underpin sciences for future European innovation and industrial advances.

Technologies that are essential for a competitive and dynamic European economy and that address the key challenges of sustainable development, combating climate change and solving energy crisis, will rely on advances in the chemical and molecular sciences. By promoting excellence in science research and in education and training, EuCheMS furthers the aims of the European Research Area.

Nineta Majcen

Secretary General

Introduction to the energy storage challenge: which contribution from chemical sciences?

Prof. Ulrich Schubert, EuCheMS

Europe faces vast challenges in securing a sustainable, affordable and plentiful supply of energy in the future. To this end, an alternative energy portfolio must be exploited. Of the available options, the most abundant and versatile is solar energy, in addition to secondary sources such as wind, biomass, hydro and ocean currents. With the associated trend towards more decentralized power generation, issues of energy transportation and energy storage become more pressing. This energy 'puzzle' requires multidisciplinary input from across the scientific and technological landscape.

Substantial breakthrough is needed for efficient energy storage technologies on both the small and large scale to balance intermittent supply with variable consumer demand. Energy storage requires transformation of electrical energy in other forms of energy, such as gravitational, thermal, kinetic or chemical energy. Every chemical reaction, i.e. every transformation of one compound in another, is associated with consumption or release of energy. Such chemical transformations can thus be used for energy storage. The general idea behind this is to produce some substance with the help of electrical energy, or directly by means of solar energy, and then use these substances – at another time and another place – to release the stored energy. The workshop will highlight the opportunities for Europe to compete in this future-oriented and challenging area with tremendous economic and societal impact and will outline the central contributions of the chemical sciences.

There are mainly two possibilities to store energy as chemical energy. The first are physical devices, such as batteries or super-capacitors, and the other is the storage of energy in the chemical bonds of molecular compounds (fuels).

New or improved materials are needed to improve the performance of physical energy storage devices and thus to achieve, for example, enhanced specific power and energy densities, longer calendar and cycle lives, better recyclability and durability, enhanced safety of the devices, reduced charging times, or replacement of strategic and expensive materials. This requires major efforts of electrochemistry and surface chemistry, as well as the development of new materials and improved modelling of thermodynamics and kinetics.

Fuels such as coal, gasoline or alcohols, are the dominant form of chemical energy storage, both in electrical generation and energy transportation. All of these substances are readily converted to mechanical or electrical energy. Instead of using fossil fuels, chemical compounds can be produced from renewable resources, and the stored energy released by "burning" these compounds. In this respect, hydrogen will be a key energy vector. The preferred renewable options include electrolysis of water, photochemical or thermochemical water splitting and photocatalytic hydrogen extraction from renewable organics as well as steam reforming of renewable fuels. Significant research is required before any of these

methods will become competitive with conventional processes, and new materials and techniques to harness hydrogen are needed in the move towards a hydrogen economy.

"Power to gas" is a technology which converts electrical energy in fuels. Next to using hydrogen directly, a second method is to combine the hydrogen with carbon dioxide and convert the two gases to methane. A great breakthrough would be the production of carbon-based fuels (or chemicals in general as feedstock for the chemical industry) directly from carbon dioxide and water with the help of solar energy on a commercial scale, this mimicking photosynthesis, nature's way of making fuel from sunlight.

Sustainable energy production, transport and storage of energy is creating enormous scientific and technological challenges and is the most crucial issue for enabling the European Union to realise its vision of becoming an 'Innovation Union'. The chemical sciences are dedicated to play a pivotal role in this process but there is still a long way to go.

Speakers

António Correia de Campos, MEP

Chairman of STOA

Professor Correia de Campos was born on December 14th, 1942 in Viseu, Portugal. A university professor (Universidade Nova de Lisboa) with a law degree from Coimbra University (1966), a 'Directeur d'Hopital' diploma from ENSP, France (1969), an MPh from John Hopkins University (1978) and a PhD in Health Economics from Universidade Nova de Lisboa (1982).

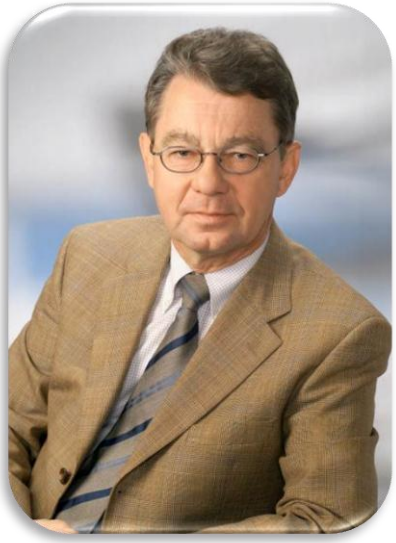
For three years (1986-89) he was director for Science and Technology at the Luso American Development Foundation (Lisbon). Mr Correia de Campos was a member of the National Parliament (1991-93), Secretary of State (1976 and 1979-80) and Minister of Health (2001-02; 2005-08).

He has also worked as a member of the Committee on Health Services Research, WHO/EURO (1984-88), on top of as a Senior Health Care Management Specialist for the World Bank (1992-95).

He is presently a Member of the European Parliament and Chairman of the Science and Technology Options Assessment (STOA) Panel.

Ulrich Schubert

EuCheMS President



Prof. Ulrich Schubert, EuCheMS, studied chemistry and got his PhD degree at the Technical University of Munich. His PhD thesis (1974 with E. O. Fischer) was in the area of organometallic chemistry. Following a postdoctoral year at Stanford University with W. S. Johnson on organic synthesis, he returned to the Technical University of Munich to work on his Habilitation (1980) on X-ray structure analyses of metal complexes. From 1982 to 1994 he had the position of an Associate Professor of Inorganic Chemistry at the University of Würzburg, and since 1989 additionally served in different leading positions at the Fraunhofer Institute of Silicate Research (ISC) in Würzburg. In 1994 he was appointed to the Chair of Inorganic Chemistry at the Institute of Materials Chemistry of Vienna University of Technology.

The current research interests of his group are focussed on sol-gel processes, inorganic-organic hybrid materials, and nanocomposites, ranging from fundamental research to applications. His publication record comprises more than 500 research papers and review articles, as well as 11 patents and 10 co-authored or edited books. He is member of the Austrian Academy of Sciences and the German Academy Leopoldina, and Fellow of the Royal Society of Chemistry. In 2009 he received the Wacker Silicon Award. Ulrich Schubert served the scientific community as the president of the Austrian Chemical Society from 2001 to 2004, as well as member of panels of several national and international funding organizations (including ERC) and boards of scientific journals. He is president of the European Association for Molecular and Chemical Sciences (EuCheMS) for the period 2011-2014.

Niyazi Serdar SARICIFTCI

Founding Director of the Linz Institute for Organic Solarcells (LIOS) at the Johannes Kepler University of Linz/Austria

Prof. Sariciftci is Ordinarius Professor for Physical Chemistry and the Founding Director of the Linz Institute for Organic Solarcells (LIOS) at the Johannes Kepler University of Linz/Austria since 1996.

He studied at the University of Vienna (Austria) and graduated with a PhD in physics in 1989. After two years of postdoctoral study at the University of Stuttgart (Germany) he joined the Institute for Polymers and Organic Solids at the University of California, Santa Barbara, USA, by Prof. Alan J. HEEGER, Nobel leaurate 2000 for Chemistry. He is the inventor of conjugated polymer and fullerene based solar cells. Prof. Sariciftci published over 500 publications and with over 30000 citations (h-index of 75) he is ranked in 2011, by Thompson Reuter as No: 14 of the world's material scientists. Sariciftci has composed 8 books and educated several academic and industrial scientists, initiated seven spin off companies. He is recipient of several prizes among them the National Science Prize of Turkey 2006 and the Austrian Scientists of the year Prize for Research 2008 and in 2012 Wittgenstein Prize of Austria. He is a Fellow of the Royal Society of Chemistry (FRSC), Fellow of SPIE, and members of American Chemical Society, Materials Research Society, Austrian Chemical Society and Austrian Physical Society. Sariciftci has been awarded an honorary doctorate by the Abo Academy in Finland in 2011 and University of Bucharest in Romania in 2012.

Key message

To fully utilize the potential of fluctuating renewable energies we have to discover methods to store and transport them in large scale. The chemistry R&D is a very important player in solving this problem.
Chemists in all fields, working on batteries, on super-capacitors as well as on chemical energy storage are offering strategies. To overcome the large scale energy storage problem in future we need the chemical conversion of renewable energies into artificial, transportable fuels.
This can be done for example by recycling CO2 into synthetic hydrocarbons which are herewith CO2 neutral. Such attempts are essential steps to create a clean, distributed energy future with a contribution to world peace.

Gabriele CENTI

President of the European Research Institute of Catalysis (ERIC).

Gabriele Centi is full professor of Industrial Chemistry at the University of Messina, Italy, and President of the European Research Institute of Catalysis (ERIC). Research interests are in the areas of applied heterogeneous catalysis, sustainable energy and chemical processes, and environment protection, including the reduction of greenhouse gas emissions by catalytic technologies.

He was coordinator of the EU Network of Excellence IDECAT and a former President of the European Federation of Catalysis Societies (EFCATS). He is actually vice-President of the Int. Association of Catalysis Societies (IACS).

He received various awards, the last being the award in Frontiers of Chemical Energy Science (2013). He is Chair of editorial board of Wiley-VCH journal *ChemSusChem*, Chief Editor of the Book Series *Studies in Surface Science and Catalysis* (Elsevier) and *Green Energy* (De Gruyter). He is also member of the International Committee of various scientific journals and conferences.

Abstract - Artificial photosynthesis

Developing an "artificial leaf" that collects energy in the same way as a natural one is potentially the solution solving the problems of sustainability of energy.[1] To avoid intermittency of solar energy, it is necessary to design systems that directly capture CO_2 and convert it into liquid solar fuels that can be easy stored.[2] Solar H_2 production is as a necessary, but intermediate step, due to the storage difficulties of this gas. Artificial leaves, to be advantageous over natural ones, should have a higher solar-to-chemical conversion efficiency, provide directly the fuels which can be then used in power-generating devices, and finally be robust and of easy construction.

The lecture will first shortly introduce the motivations why chemical energy storage is the key for a sustainable use of solar energy and for the introduction of renewable energy into the energy and chemical value chain, to present then some key recent progresses in producing solar fuels and artificial leaves.[1,3] The perspectives and roadmap in going to artificial leaves are finally remarked.[3-5]

References:

[1] S. Bensaid, G. Centi, E. Garrone, S. Perathoner, G. Saracco, *ChemSusChem* 2012, 5, 500.
[2] G. Centi, S. Perathoner, *ChemSusChem* 2010, *3*, 195-208.
[3] G. Centi, S. Perathoner, in *Chemical Energy Storage*, R. Schlögl (ed.), De Gruyter Pub.: Berlin 2012, Ch. 5.1, pp 379-400. ISBN: 978-3-11-026632-0
[4] G. Centi, S. Perathoner, R. Passalacqua and C. Ampelli, in *Carbon-Neutral Fuels and Energy Carriers*, N.Z. Muradov, T. Veziroğlu (ed.s), CRC Press (Boca Raton, FL - USA) 2011, Ch. 4, pp. 291-324.
[5] G. Centi, S. Perathoner, DS Su, *Angew. Chemie Int. Ed*. 2014, submitted.

Neil Champness

Professor of Chemical Nanosciences at the University of Nottingham, UK

Neil Champness is the Professor of Chemical Nanosciences at the University of Nottingham, UK. His research spans chemical nanoscience and all aspects of molecular organization. His research achievements have been recognised by the award of a number of Royal Society of Chemistry prizes including the Corday-Morgan Medal and Prize (2006), Supramolecular Chemistry Award (2010) and a Royal Society Wolfson Merit Award (2011). He has been a Visiting Professor at Institute Of Chemistry – UNESP, Brazil (2009), the Institut Le Bel, University of Strasbourg, France (2011) and the University of Adelaide (2014). Neil is a Senior Advisor to the British Council on matters relating to Science and Engineering, a Fellow of both the Learned Society of Wales (FLSW) and the Royal Society of Chemistry (FRSC). In 2011 he was identified as one of the top 100 most cited chemists of the previous decade.

Chemical aspects of hydrogen technology

The talk will focus on chemical methods and technologies for exploiting hydrogen as a fuel. Emphasis will be made on the issues surrounding the storage of hydrogen, particularly for mobile applications, and the challenges that need to be overcome. The talk will highlight how distinct chemical approaches provide potential solutions to these problems and great promise for enabling new technologies.

Ferdi Schüth

Director of the *Max-Planck-Institut für Kohlenforschung*

Prof. Ferdi Schüth was born in 1960 in Warstein.

He studied Chemistry and Law in Münster. He received his doctorate in Chemistry in 1988 and passed the First State Exam in Law in 1989.

In 1995 he became Professor in Chemistry and worked till 1998 as such at the University in Frankfurt.

Since 1998 he is Director of the *Max-Planck-Institut für Kohlenforschung* (Mülheim an der Ruhr).

Ferdi Schüth received several awards, e.g. *Award of the Stifterverband der Deutschen Wissenschaft*, *Gottfried-Wilhelm-Leibniz-Award*, *Wöhler-Award* and *Hamburger Wissenschaft-Award*.

He is member of numerous editorial boards and committees, e.g. *Dechema*, *DFG,* selection committee of the *German Future Award,* Professor h.c. at the Dalian University (China) and founder of the *hte AG*.

His research field comprises energy, biomass conversion, crystallization processes, synthesis of catalyst materials, catalysis, zeolites, ordered mesoporous materials and hydrogen storage materials.

Abstract

Energy storage is one of the key questions in energy systems with a high fraction of intermittent supply, together with grid extension, back-up capacity, and demand side management. The presentation will briefly discuss storage options with relevance on the grid scale, such as large scale batteries, distributed battery systems, and chemical storage options.

Kristina Edström

Ångström Advanced Battery Centre, Uppsala University, Sweden

Kristina Edström is professor in inorganic chemistry and director of the Ångström Advanced Battery Centre, Uppsala University, Sweden. She heads a team of 40 battery scientists with a history of scientific and industrial success. All aspects of lithium battery materials, new cell concepts (Li-O2, Li-S) and sodium batteries are studied with a wealth of different techniques. Special emphasis is on battery stability and the reactivity occurring at battery material interfaces. She has authored more than 125 international publications. Edström is in the board of the European Institute of Technology KIC InnoEnergy and coordinating StandUp for Energy (an energy research alliance between four universities). She is frequently invited as speaker at international conferences and a board member of the Battery Division of the Electrochemical Society. She is a member of FP7 and ERA-NET programs focused on lithium- batteries and of the ALISTORE-ERI network since its start in 2003. She is a board member of the Swedish Foundation of Strategic Research and of the MAXIV Laboratory. She is a member of The Royal Academy of Engineering Sciences and The Royal Society of Sciences.

Abstract

Large amounts of materials will be needed for building energy storage in the form of batteries to fulfill the expectations of fossil-free transportation. This will put strain on resources and recycling procedures. This presentation high-lights some routes to take for sustainable development of new functional materials. The possibilities are ample and new materials as well as new processes to improve existing materials are constantly presented. One message is that we have to continue to live with a number of different choices of materials and batteries depending on the type of application we will use. In some cases power-optimisation is important for fast charging of devices and in other cases high energy density will be the necessity; the size of the battery is important for vehicles but less important for other systems. We will have to start thinking about our limited resources of raw materials in a more focused way: inorganic dense materials for small compact batteries and organic materials from renewable sources for applications needing less energy which can allow larger size batteries. Hopefully, the presentation will show how stimulating the hunt for new materials for smart energy storage is for material scientists and how useful this hunt can be also from an innovation point of view.

Fabrice STASSIN

Managing Director of the EMIRI Association (Energy Materials Industry Research Initiative
Represents Umicore

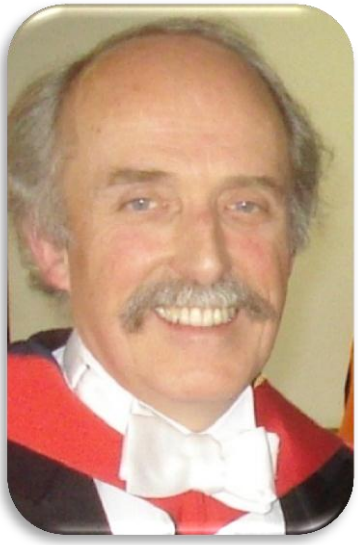
Dr Fabrice Stassin is Managing Director of the EMIRI Association (Energy Materials Industry Research Initiative – www.emiri.eu). He holds a Diploma and PhD in Chemistry from the University of Liège in Belgium. Fabrice Stassin joined Umicore in 2008 as Innovation Project Manager covering the scope of clean technologies of interest to Umicore with later a focus on thin-film photovoltaics . Since 2012, he is part of the Brussels-based team of Umicore Government Affairs focusing on Energy Materials. Fabrice Stassin was instrumental in the development of the EMIRI Association which he now manages. EMIRI aims at establishing Industrial Leadership in EU in the field of Advanced Materials for low-carbon energy technologies through involvement of all stakeholders in strategic research & innovation programmes.

Abstract

The talk will illustrate the role that advanced materials play in enabling energy storage technologies more particularly in the case of battery technologies – The talk will also outline the main topics of innovation needed to develop these battery technologies further.

David Cole-Hamilton

President of the Royal Society of Chemistry's Dalton Division and President-elect of EuCheMS



Following studies in Edinburgh (BSC, 1971; PhD, 1975), David Cole-Hamilton worked with Sir Geoffrey Wilkinson at Imperial College as a Postdoctoral Fellow and Temporary lecturer. A Lectureship and Senior Lectureship in Liverpool were followed by appointment to the Irvine Chair of Chemistry at the University of St. Andrews in 1985. His research interests concern the applications of Oranometallic Compounds to solving problems in Homogeneous Catalysis and Materials Science. He is interested in the chemical manipulation of waste bio-oils, in developing new catalytic reactions and in carrying out catalysis flow systems. He is currently President of the Royal Society of Chemistry's Dalton Division and President-elect of EuCheMS.

Abstract

Only one form of energy comes into the earth – radiation from the sun. 10 % conversion of the sun's radiation landing on an area the size of Libya would give enough energy to power all the needs of the whole world. Eventually, we shall have to rely on solar energy through different methods of conversion – wind, wave, currents, hydroelectric, passive solar, photovoltaics etc. All of these are fickle, producing excess energy at some times and none at others. Thus, the efficient storage of energy is one of the key factors that will help us to maintain or improve our standard of living as the oil depletes and as we reduce carbon emissions to combat global warming, sea-level rise and climate change. Chemical methods of energy storage will be pre-eminent, whether in batteries or in high energy compounds.

This is a publication of the
STOA Secretariat
Directorate for Impact Assessment and European Added Value
Directorate-General for Parliamentary Research Services

European Parliament
Rue Wiertz 60
B-1047 Brussels
Tel. +32 2 284 22 36
E-mail: stoa@europarl.europa.eu

www.europarl.europa.eu/stoa PE 513.556