Report of the meeting held under the auspices of the ESF EUROCORES programme on Solar Fuels.

a) Summary

This meeting took place at the Buchanan Arms Hotel in Drymen just north of Glasgow from the 29th to the 31st of October. There were 63 participants. 11 different countries including USA and Japan were represented. Considerable effort was taken to ensure the participation of early career scientists and just under 50% of the participants were in this category.

The programme consisted of talks, poster sessions and two open discussion sessions. The first group of talks presented the details of the individual programmes of not only the two EUROCORES SolarFuels groups (Glasgow and Leiden) but also the similar groupings in Arizona (Tom Moore), St Louis (Bob Blankenship), Chicago (Alex Martinson), Osaka (Hideki Hashimoto) and Imperial College (James Durrant). The second group of talks went into more detail of the science being undertaken to meet the solar fuels' challenge. It was also helpful that Professor Lionel Clarke from Shell UK was present and gave a talk as he was able to give an industrial prospective and because he has recently written the UK roadmap for Synthetic Biology. This roadmap highlights the importance of Synthetic Biology in the field of Bioenergy. The Royal Society of Chemistry and the BBSRC were also represented.

Final programme

Monday 29th October

12:00 – 14:00	Registration & check-in Buffet lunch with arrival tea, coffee & biscuits
14:00 – 14:30	Welcome by Professor Richard Cogdell
	Session one *- Summary of the different solar energy research groups represented at this EUROCORES conference*
	Chair – Richard Cogdell
14:30 – 15:00	Professor Huub de Groot – The Solarfueltandem project
15:00 – 15:30	Professor Tom Moore – Arizona Energy Frontier Research Centre BISFUEL
15:30 – 16:00	Afternoon tea, coffee & biscuits
16:00 – 16:30	Professor Bob Blankenship – St Louis, Energy Frontier Research Centre PARC
16:30 – 17:00	Professor Lee Cronin – BOLDCATS

18:30	Dinner

Tuesday 30th October

07:30 – 09:30	Breakfast
	Session two *- Summary of the different solar energy research groups represented at this Eurocore conference*
	Chair – Alfred Holzworth
09:30 – 10:00	Professor Wolfgang Lubitz – Research from the Max Planck Institute for Renewable Energy
10:00 – 10:30	Professor Hideki Hashimoto – Energy in Environmental Research in Osaka OCARINA
10:30 – 11:00	Mid morning tea, coffee & biscuits
11:00 – 12:00	First poster session
12:00 – 13:30	Two course buffet lunch
13:30 – 14:30	First discussion session – How to choose which solar fuel to make?
14:30 – 15:00	Professor James Durrant – Solar Energy Research at Imperial College London
15:00 – 15:30	Afternoon tea, coffee & biscuits
	Session three – *New devices & concepts*
	Chair – Tom Moore
15:30 – 16:00	Dr Erwin Reisner – Solar water splitting with enzymes and synthetic catalysts integrated in nanostructured materials
16:00 – 16:30	Dr Alex Martinson – Improving solar fuels through surface chemistry, the versatility of atomic layer deposition
16:30 – 17:00	Professor Bruno Pignataro – Improving light harvesting and energy conversion by organic thin film bulk heterojunctions
17:00 – 17:30	Professor Alfred Holzwarth – Design of stable artificial antenna/charge separation devices for driving artificial

	photosynthesis
17:30 – 18:30	Second poster session
19:00	Dinner

Wednesday 31st October

07:30 – 09:30	Breakfast
	Session four – *New devices & concepts*
	Chair – Lee Cronin
09:30 – 10:00	Lionel Clarke – Future Fuels - Challenges and Opportunities
10:00 11:00	Second discussion session - Defining the solar fuel road map (i.e. what does the next 15 years look like for research, innovation and investment)
11:00 – 11.30	Mid morning tea, coffee & biscuits
11.30 – 12.00	Meeting closes

Scientific content of event and results & impact

Discussion sessions & poster sessions.
The first discussion session addressed the question '**How to choose which Solar Fuel to Make**'. The first clear point made was that we have plenty of cheap, readily accessible fossil fuels available that will always beat the price of renewable energy, especially solar fuels. However this assumes that increasing levels of atmospheric Carbon Dioxide are not a problem. Once this is accepted as a problem (and most of the participants did) then the case solar fuels is clear. The first alternative and the most easily achievable is hydrogen. There was considerable discussion on the best way to make hydrogen and to store it. It was clear that at this stage as many options as possible need to be tested. It was also pointed out that hydrogen is not only a good fuel but is required in very large amounts for the Haber/Bosch process to produce ammonia. Even if hydrogen produced as a solar fuel was only used in this process it would save a lot of fossil fuels that are currently used. The general view was that great progress is currently being made in studies developing systems capable to sustaining the water splitting reaction using earth abundant and cheap metals. This then is hopeful for hydrogen production. The more challenging problem is to produce solar fuels based on carbon, especially trying to fix carbon dioxide at its atmospheric concentration of 0.04%. This is a really important challenge. Success in this area would not only reduce atmospheric carbon dioxide but

also produce fuels that can be used with current combustion engine technology. Both these are critical points to bear in mind. This discussion session was highly structured and therefore was well focussed.

The group was clearly divided into those going for hydrogen and those going for carbon-based fuels. Both lines of research are critical to pursue.

The second discussion session concentrated on '**A road map for solar fuel research**'
This discussion session was deliberately left much more open to see if new ideas could be elicited. It was very clear that this road map will define a long term research project and this will require a lot of work to persuade the politicians and the funders to take a long term view. A suggested horizon was 30 years. This is very hard to achieve and will need a deliberate effort to get public opinion on board and to get a funding commitment that goes well beyond the time of any single European parliamentary term. It was also thought to be important that such a research program should have milestones that could demonstrate 'wins' along the way. One of these could be hydrogen production powered either by solar energy directly or from electricity provided by solar cells. Lionel Clarke presented Shell's biofuels program. It was clear why Shell were doing this but not many in the audience thought it was a good idea.
There was a big effort to try to get the Early Career researchers to think about putting together a road map, since they would be the ones carrying it through. Unfortunately they were too shy. They were asked then to go home and think about it for our next meeting.

It was suggested that this issue be revisited next time. The participants were asked to tackle this in a structured way by thinking of the challenges at each step and then ordering them into a timeline, thereby constructing a road map. The session ended with lots of small group discussions continuing.

The meeting put the EUROCORES programme into a firm international context. It was also very successful in networking both the EUROCORES groups together. The two groups are highly complimentary and several areas were we can collaborate in the future have been identified. It was therefore very positive overall. The venue was especially good since being in a small village everybody stayed together and this certainly strongly enhanced the interactions.

b) List of speakers and participants

(speakers)
Khuram Ashraf
Monica Barroso
Deirdre Black
Bob Blankenship
Leanne Bloor
Michael Booth
Anne-Marie Carey
Mariya Chepisheva
Lionel Clarke

Richard Cogdell
Alexander Cowan
Lee Cronin
Nikodem Czechowski
Huub de Groot
James Durrant
Thomas Eisenmayer
Alastair Gardiner
Daniel Gryko
Kirsty Hacking
Hideki Hashimoto
Sarah Henry
Andrew Hitchcock
Alfred Holzworth
Michael Hornak
Masahiko Iha
Andreas Johansson
Joanna Kargul
Dorota Kowalska
Tomasz Krupnik
Yi-Hsuan Lai
Petar Lambrev
Florian le Formal
Chia-Yu Lin
Peter Lindblad
Heiko Lokstein
Wolfgang Lubitz
James MacDonald
Sebastian Mackowski
Alex Martinson
Yuliya Miloslavina
Pedro Molina-Sanchez
Adriano Monti
Tom Moore
Rachel Mulvaney
James Murray
Julian Olmos
Steph Pendlebury
Federico Pesci
Bruno Pignataro
Robin Purchase
Simon Puttock
Ben Raush
Erwin Reisner
Anna Reynal
Bruno Robert

June Southall
Yuko Sugai
Mark Symes
Anna Tarnowska
Brijith Thomas
Olena Vakulyuk
Rienk van Grondell
Stephen Watson