PROJECT SUNSHINE – THE SCIENCE BEHIND FOOD AND ENERGY SUSTAINABILITY

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The world is entering a period of crisis: there is not enough energy or food and their costs are rising; there is environmental destruction and loss of biodiversity at an accelerating rate; and there is increasing evidence of potentially catastrophic climate change. A common feature is the unsustainable nature of most human activity. The University of Sheffield has realigned its science research, creating Project Sunshine, to discover sustainable routes to food and energy security through collaborative research and innovation, uniting scientists across the traditional boundaries in both the pure and applied sciences.

Prior to the industrial revolution, limits on population and human activity were set by the sun, and by the productivity of the land. The discovery and use of fossil fuels changed everything – rather than being constrained by the supply of energy from the sun, mankind could use the energy of the sun's action that had been accumulated and "stored" underground for hundreds of millions of years. This apparently limitless supply of energy drove an unprecedented period of growth in human population and technological development. Our use of fossil fuel thus creates a massive historical anomaly: unsustainable growth in demand for energy and food; unsustainable drain on the earth's finite natural resources; unsustainable environmental degradation; unsustainable pollution of our atmosphere. Only by re-making the link between the sun and human activity can we again establish sustainabilty. This will involve the development and deployment of new technologies and systems that use the sun's energy more efficiently and more extensively to increase food production and provide renewable energy at the same time reducing carbon emissions, decreasing environmental degradation and stabilising atmospheric CO_2 levels.

THE TRANSITION TO A SUSTAINABLE ECONOMY

Achieving this goal of sustainability will not be easy. In the case of food, analysis of population growth, agricultural productivity and environmental sustainability presents a bleak scenario – too many people, not enough yield, not enough land, not enough water, too much pollution, increased energy (and carbon) costs, and the uncertain consequences of global warming. According to the Global Food and Farming Futures Report, world food production will need to increase by at least 50% in the next 20 years, a massive rise in harvestable yield per hectare of the major crops such as rice and wheat. In the case of energy, similar analyses suggest the requirement to increase energy supply by an incredible 2-3 times, to around 30 TW by 2050. In this new scenario, there is no alternative but to dramatically change the way we use and produce energy and food, to adapt to the already changed climate and to ameliorate the extent of future change. All levels of human activity in all parts of the world will be affected. The United Kingdom should position itself, just as it did in the industrial revolution, to lead this change – easing the transition to a sustainable economy by scientific research and technological innovation.

SOLUTIONS PROVIDED BY INTERDISCIPLINARY SCIENCE AND NEW TECHNOLOGY

Whilst some view science as the enemy of sustainability, it is only by scientific research and

technological innovation that we can achieve such sustainability whilst at the same time preserving and enhancing the quality of life for all the citizens of the world. In Project Sunshine we identify the problems of food and energy sustainability and global change as being inextricably linked, thus requiring integrated approaches. Solutions to the global problems of energy and food security will emerge from the integration of knowledge to examine complete systems – approaches derived from the expertise of biologists, physicists, chemists, engineers, and mathematicians, in the context of the perspective offered by geographers, psychologists, sociologists and economists. The complete system extends all the way from physical, chemical and biochemical mechanisms at the atomic and molecular levels to the processes, operations and technologies embedded in our socio-economic system. Furthermore, whilst investigation of some specific aspects of food or energy production might be distinct, the common underlying theme (of using science to provide sustainability) will serve to unite scientists, give extra urgency to their work and be a key driver of the all-important process of public engagement. Project Sunshine thus provides a model for the route from basic research to impact. Let us set out some examples of the approaches being taken.

AGRICULTURAL IMPROVEMENT

Modern agriculture, in essence, converts oil into food, consuming vast quantities of water and producing a variety of pollutants. Replacing oil with renewable energy would only solve part of the problem – we also need to reduce consumption of water and decrease the amount of fertiliser applied to the land. This will require improved varieties of crops with not only higher yields per unit land area, but also with more efficient use of water and fertiliser, and less reliance on pesticides. There will not be a single solution – different crops in different geographical locations under different management conditions will demand a range of different solutions. In Project Sunshine we are engaged in research aimed at fundamentally increasing the efficiency with which cereal crops use light, water and fertiliser by changing the basic biochemical pathway of photosynthesis – this work comprises a large consortium of researchers in Europe, USA and Asia. In other projects research into the mechanisms that determine how the leaves of plants respond to environmental stress will provide the knowledge needed to make crops more resistant to the effects of extremes of weather. Similarly, another major aim is understanding the mechanisms of resistance of crop plants to the invasive parasites that drastically reduce crop yield in many areas of the world. A further strand of research concerns the sustainable and efficient provision of nutrients by the soil, in particular understanding the complex interactions between plants and soil microbes, knowledge that could lead to an agriculture less dependent on fossil-fuel based inputs and with much lower impact on the environment.

SOLAR ENERGY

With the same theme of utilising solar energy more efficiently, physicists and chemists in Project Sunshine are developing new materials for the next generation of photovoltaic solar cells. At the same time it is important to establish exactly how efficient these will be compared to existing technology, and a Solar Farm has been built to provide a test bed, producing readily accessible standardised datasets of solar cell performance under everyday conditions. Bringing in new ideas generated in biology is also an important aspect of our work. The collection of light energy in natural photosynthesis in plant and microbes is highly efficient and robust, and integration of biomolecules into semiconductors to create hybrid devices is a particularly exciting innovation that has great promise. Direct use of plants and microbes to produce biofuel and other useful feedstocks is another important area of activity. Microalgae are particularly suitable for this purpose. Here our process engineers are collaborating with biologists to develop commercial scale systems in which algal cultures convert the CO_2 emitted from industrial steel plants into bio-diesel, a technology that could find widespread use and contribute to reducing CO_2 emissions by means of carbon capture.

GLOBAL CHANGE

All of this work is set against the backdrop of significant studies into global change. A major activity is understanding the role of the terrestrial biosphere in the contemporary and future carbon cycle, and especially the use of satellite (and ground data) to constrain carbon cycle calculations by models. We also do basic science on the interrelations of organisms and environment. How have ecosystems responded to past episodes of global change, what effects do plants have on the Earth System, and what are the impacts of contemporary climatic variation and anthropogenic global change on plants? Armed with this understanding we are able to evaluate the likely impacts of contemporary global change on the world's flora. We examine how people respond to climate change. What are their fears? How do they respond to low carbon-generating technologies and change their behaviour to reduce individual environmental impact? Alongside such large scale international research we also carry out small scale but equally significant projects with more immediate practical application. eg developing new material for living architecture, such as foams which can be used to make green walls and roofs.

ENGAGEMENT AND COMMUNICATION

Project Sunshine, along with activities of a similar nature in other institutions in the UK and worldwide, provides a model for a new way of thinking about and doing science, which is focused on innovative pure science, but at the same time geared toward providing practical solutions. A vital part of this process is engagement and communication with individuals and organisations from across areas of academia, business and the public sector, and with the general public. With this aim in mind, in September we are hosting a major event, the Shine 2011 International Conference, which will be supported by the UK Research Councils and a number of commercial organisations including BP.

http://shine.sheffield.ac.uk/