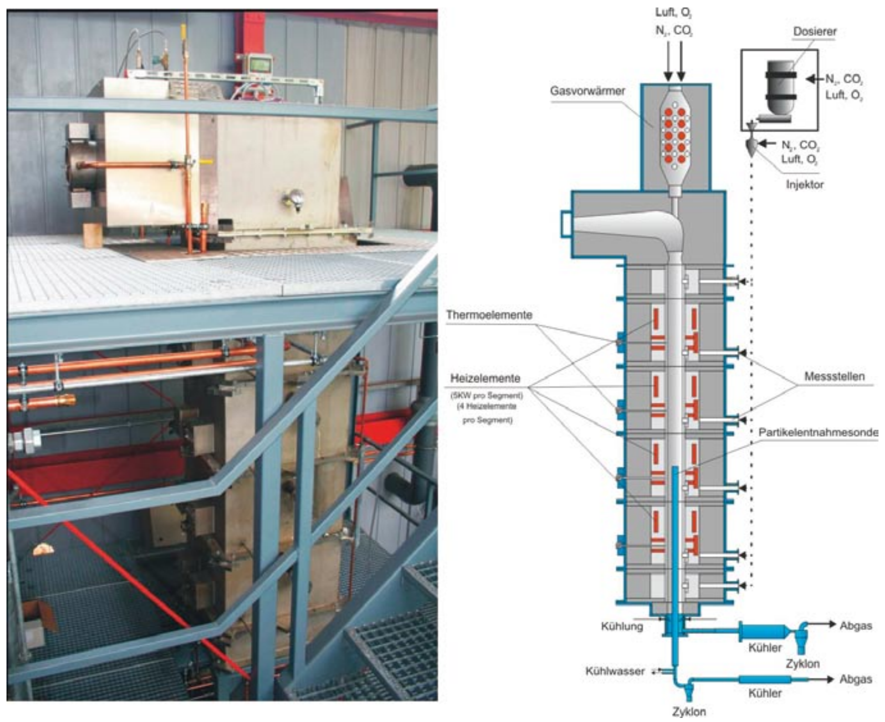
Demand for energy is growing in parallel with concern over the environmental impact of energy conversion processes. **Professor Roman Weber** of the INSPIRE network explains how his initiative's research into system optimisation will improve the efficiency of energy usage

Highly Skilful Specialists for the World Energy Market

The world's total primary energy supply currently amounts to around $11x10^9$ toe (Tonne of oil Equivalent) per annum ($462x10^{18}$ Joule/annum). Around 80.3 per cent of this supply is provided by converting fossil fuels (natural gas, crude oil and coal) into thermal energy – mainly through combustion – while 6.3 per cent is provided by nuclear and 2.2 per cent by hydro. The remaining 11.2 per cent is provided by combustion of wood (biomass) and waste. It has been projected that by 2030 the global demand for energy will be around 1.5 times current levels of supply. Notwithstanding the need to develop alternative methods of energy conversion, through solar and wind power or biomass utilisation for example, this century will belong to fossil fuels as far as energy conversion is concerned. The effect of increased greenhouse gas emissions on the global climate has become apparent over the last two decades or so, and drastic reductions are needed if the Earth's temperature is to be kept under control. In particular carbon dioxide (CO_2) emissions must be substantially reduced if our planet is to remain inhabitable in the long run. Even those who do not buy the argument that changes in the global climate are caused by human activity accept the so-called 'no regret' policy, or the need to conserve what remains of our natural resources. In short, CO_2 emissions must be rapidly and drastically reduced, and now we must look towards the development and implementation of technologies and policies to achieve this goal.

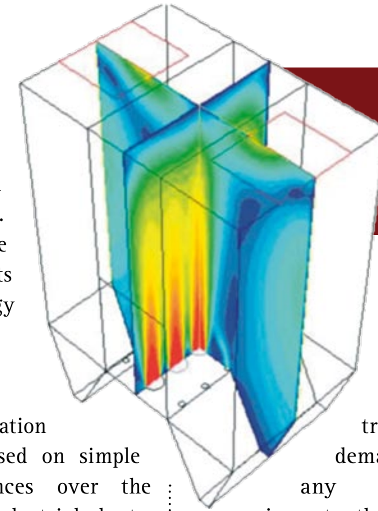


Reactor for advanced fuel characterisation

Tackling the fossil fuels sector, which accounts for around 80 per cent of the world's primary energy production, is a crucial step towards achieving rapid and substantial reductions in CO_2 emissions. Only two options are practically applicable in this area: energy savings and improving the efficiency of fuel conversion. Around 30 per cent of energy is consumed in highly energy-intensive industrial processes, while the use of so-called 'secondary fuels' – including biomass and wastes – has dramatically increased. The effect of fuel substitution on specific industrial processes and industrially generated pollutants, particularly CO_2 emissions, is of primary concern. The introduction of a Carbon Tax, and emissions trading on a regional basis, may foster the application of industrial plants containing CO_2 separation units.

A recent prognosis shows that huge investments in both the power industry and the power generating sector of the process industry must be made in the near future. The scale of the reconstruction reaches 90 per cent of current capacity, and it should take place between now and 2030. Thus, there is an urgent need to improve the existing technologies and perhaps even develop new ones, these will be based on the combustion of both alternative and conventional fuels.

The INSPIRE (Optimisation of Systems, Energy Management, and Environmental Impact in Process Engineering) network, an EU-backed initiative of which I am the overall co-ordinator, stems from the need to update existing state-of-the-art energy management and environmental impact assessment methods. This is largely due to market forces, the availability of new fuels and recently instituted environmental regulations. The ultimate objective of the project is to produce specialists in the optimisation of energy conversion and usage.



Supercritical boiler concept

The methods

Today, energy usage optimisation in industry is mainly based on simple energy and mass balances over the individual components of industrial plants, the total production level of the plant is subsequently analysed to generate a figure for overall energy consumption. Although numerous energy streams are taken into account, these are evaluated exclusively on the basis of the first law of thermodynamics. The substitution and replacement of these streams with new 'secondary fuels' is also evaluated, primarily on the basis of their energy content and preparation requirements. Within the INSPIRE project a thermo-economic analysis (TEA) and life-cycle analysis (LCA) have been used. The latter has been expanded into the Exergy Life-Cycle Analysis (ELCA), which offers a unique opportunity to provide the optimum framework for comparing and assessing different technological options for carbon/CO_2 separation and sequestration.

Computational Fluid Dynamics (CFD) has made a tremendous impact in high-tech industries over the last decade or so; new aeroplanes and engines have been designed using CFD. CFD is also used in both the process and power-generating industries to assist in process design. However, it is perhaps fair to say that the successful application of CFD in the design of combustion chambers still remains an art. This is largely because of its technical complexity; the CFD user must possess a more complete understanding of numerical methods, the physics of reactive flows and also heat transfer and chemistry, a demanding combination by any standards. More importantly, the CFD user is often in no position to assess the quality of the predictions unless he or she possesses measured data. The INSPIRE network has provided young engineers with the opportunity to conduct fuel characterisation experiments and develop fuel specific sub-models. This has been followed by comprehensive CFD simulations of semi-industrial and industrial scale plants.

> "The effect of increased greenhouse gas emissions on the global climate has become apparent over the last two decades or so, and **drastic reductions are needed if the Earth's temperature is to be kept under control**"

The output

The research carried out by the INSPIRE network has advanced both the theoretical and experimental methods used in energy engineering. Details can be found in the 15 scientific papers written by myself and my colleagues, as well as the 50 conference presentations made by network researchers, while two books are currently in the process of being prepared for printing. However, there is no doubt that the main achievement of the network is the training of a number of engineers experienced and confident in using modern design methods. Altogether, thirty-three young researchers possessing an M.Sc. degree (or its equivalent degree) have spent between six months and three years gaining experience in both industry and academia. While working on the network, four researchers defended their Ph.D.exams, and another seven are likely to do so in 2010. ★

At a glance

Full Project Title

Optimisation of Systems, Energy Management, and Environmental Impact in Process Engineering (INSPIRE)

Project Partners

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