Tyndall Centre
for Climate Change Research

the effect

Highlighting research at the Tyndall Centre

2002

Seeing the future
Climate change in the UK
Low carbon energy and transport futures
International vulnerability, justice and equity

About the Tyndall Centre for Climate Change Research

Global climate is changing. Society must consider options to mitigate future climate change by reducing greenhouse gas emissions from transport, energy generation and industry, and finding new ways to sequester carbon through safe storage. Society must also consider the necessity for adaptation to reduce the impacts of those changes to which we are committed. By promoting informed dialogue, the Tyndall Centre aims to motivate society to choose our future climate. Tyndall Centre researchers are developing sustainable solutions to climate change and aim to exert a seminal influence on UK and international climate policy. We bring together climate scientists, social scientists, engineers and economists from academic institutions around the UK in a unique collaborative, trans-disciplinary research effort.

The Tyndall Centre's headquarters are at the School of Environmental Sciences at the University of East Anglia (UEA), with two regional offices at the University of Manchester Institute of Science and Technology (UMIST), and the University of Southampton and Southampton Oceanography Centre (SOC). The full Tyndall consortium also includes the University of Cambridge, NERC's Centre for Ecology and Hydrology (CEH), SPRU – Science and Technology Policy Research – at the University of Sussex, the University of Leeds' Institute for Transport Studies (ITS), Cranfield University's Complex Systems Management Centre and the Energy Research Unit at the CLRC Rutherford Appleton Laboratory (RAL). The Centre's core funders are the Natural Environment Research Council (NERC), Engineering and Physical Sciences Research Council (EPSRC) and Economic and Social Research Council (ESRC), with additional support from the Department of Trade and Industry (DTI).

the effect highlights the past year's activities of the Tyndall Centre for Climate Change Research. It is named after the Tyndall Effect, a special instance of diffraction discovered by John Tyndall, where a light beam is made visible by a suspension of very fine particles, for example headlights in a fog or sunbeams in dust.

Tynd-*All*, a quarterly electronic update of the Tyndall Centre's planned activities and research highlights, is available by email. Sign up to receive Tynd-*All* at www.tyndall.ac.uk/tynd-all/tynd-all_form.shtml

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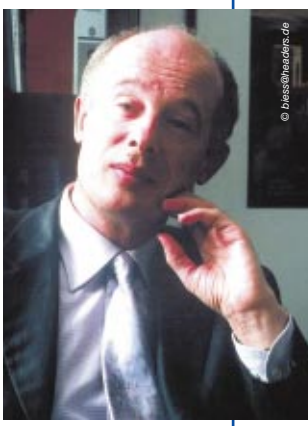
www.tyndall.ac.uk

Issued August 2002

From the Research Director . . .

Integration across disciplines and sites: is it possible?



Integration has emerged in recent years as the 'holy grail' of science, policy, assessment and planning. Joined-up thinking in government, integrated environmental policies, and inter-disciplinary science are either demanded or promised by many of our post-modern institutions. The Tyndall Centre also makes bold claims to pioneer and deliver on this objective of integration – in our case, in relation to the necessary and appropriate responses society needs to make in the face of global climate change. The Centre has been designed to cross traditional knowledge disciplines and to work co-operatively at multiple sites in the UK. And our intellectual goal is to integrate human knowledge so that the unprecedented geographic (global to local) and temporal (centuries to years) scales over which climate change operates and impacts society are adequately brought into common focus when we debate, inform and evaluate climate change policies. But can the Tyndall Centre deliver against this ambition?

It will of course require the novel organisational infrastructure we have established for conducting distributed and interactive science; it will of course require the commitment and enthusiasm that Tyndall researchers are bringing to the Centre; and it will of course also require us to think expansively and creatively about new ways of connecting knowledge through both the language of discourse and the language of quantification. But above all, it will require us to take risks, both by engaging in serious scientific discussions outside our own knowledge areas and through seeking novel research partnerships with organisations, agencies and businesses across society in the UK and beyond.

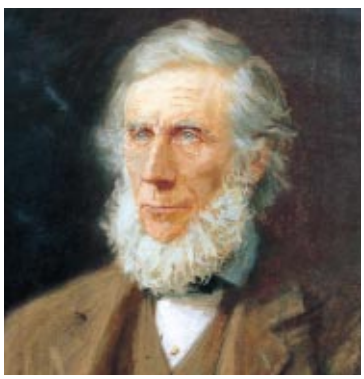
the effect is the annual newsletter of the Tyndall Centre, intended to allow our partners, stakeholders and friends to share our journey and judge how successful we have been in this enterprise.

Professor Hans Joachim ('John') Schellnhuber

August 2002

Who was John Tyndall?

The scientist after whom the Tyndall Centre for Climate Change Research is named was one of the most distinguished scientists of his generation, succeeding Michael Faraday as Director of the Royal Institution. Born in 1820 in County Carlow, Ireland, he was an inventor of many scientific instruments and devices, and a popular and accessible communicator who illustrated his lectures with exciting experiments. But it was his studies of the radiative properties of gases that laid the foundations for research into global climate change.



John Tyndall discovered that carbon dioxide in the atmosphere can regulate the planet's temperature.

Tyndall discovered that different gases, although "perfectly colourless and invisible," absorbed and transmitted different amounts of heat, and concluded that water vapour, carbon dioxide and ozone are the best absorbers of radiant heat. He verified experimentally that it was gases in the atmosphere, now known as greenhouse gases, that absorbed heat. Tyndall stated in 1859 that any changes in the amount of radiatively active gases such as carbon dioxide could have produced "all the mutations of climate which the researches of geologists reveal . . . they constitute true causes, the extent alone of the operation remaining doubtful." It wasn't until the 1930s that British meteorologist G. S. Callender related observed global warming to human-induced changes in carbon dioxide.

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Global climate is changing . . .

Tyndall Centre's new Headquarters

From summer 2003, the Zuckerman Institute for Connective Environmental Research (ZICER) at UEA will be the new location of the Tyndall Centre's Headquarters. The building's open plan will allow interaction between the Tyndall Centre and other research centres of excellence: the Centre for Social and Economic Research on the Global Environment, the Centre for Environmental Risk, and the Centre for Economic and Behavioural Analysis for Risk and Decision. A bridge will connect the groups to the heart of the School of Environmental Sciences and to the Climatic Research Unit.

Professor Trevor Davies, Dean of Environmental Sciences, says the state-of-the-art building will itself be a research project. "A glass roof and part of the south wall will have integrated photovoltaic cells to provide some of the occupant's energy needs, and will be monitored as part of a Europe-wide project into the design and integration of solar panels," he says. A roof canopy system and reservoirs of air in the hollow concrete floors will contribute to a high thermal inertia, which will ensure internal temperatures vary by less than 1ºC over the year. "In terms of energy use, the ZICER building is designed to outperform the UEA's Elizabeth Fry building, described by many architects as the best building in Europe."

The building housing the Tyndall Centre's new headquarters is named after Solly (later Lord) Zuckerman, the UK Government's first chief scientific advisor. He suggested a school of Environmental Sciences at UEA and planned its composition of interdisciplinary research groups – a revolutionary vision for the 1960s. The interdisciplinary philosophy continues today and is reflected in the Tyndall Centre's research.

For more information see: *www.rtcc.org/cop8/casestudies/research/zuckerman.*

Architecture and climate change

Improving the relationship between buildings and climate is the aim of a Tyndall project that has brought together architects, engineers, environmental scientists, economists, social scientists, and specialists from the insurance, finance and housing industries. Buildings contribute more than half of the UK's greenhouse gas emissions through their construction and energy use, so have significant potential to mitigate climate change through energy efficient design. "Increasing air conditioning is a knee-jerk reaction to climate change," says Samantha Lawton from Cambridge University's Martin Centre. "It uses huge amounts of energy and can have a negative impact on comfort and health. Natural ventilation and shade gives people more control of their environment, which leads to improved comfort in higher temperatures."

Samantha Lawton (right) and Dr Koen Steemers have brought together building industry specialists to establish research directions in sustainable building design, such as adaptation to increased risk of flood and wind damage, insurance implications and building performance in extreme temperatures.

The built environment must also adapt to inevitable impacts of climate change, such as floods, storms and subsidence. "Insurance companies could decide not to insure housing in flood plains, so a property sub-class of people with uninsured and therefore unsellable houses may evolve," says Samantha. She says the impetus to adapt must come from clients and regulators, but architects need to do more than just meet the standards.

Samantha says links between the sometimes conflicting aspects of adaptation and mitigation need to improve. "We need to make low energy, passive buildings that also respond to climate change." The findings will be disseminated through professional and academic journals and a book planned for publication in 2003.

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Third Sustainability Days

The launch of the ZICER building (above) coincides with the Third Sustainability Days (SD3). The University of East Anglia will host SD3 from 4–9 September 2003, the latest in a series of high profile international events addressing how to create a more sustainable way of living. SD3 will bring together local, national and international participants at connected lectures, workshops and social events. Topics to be covered include: Visualisation and Communication of Possible Futures; Rural and Coastal Sustainability; Area-based Decarbonisation; Climate Change, Equity and Justice; and Using Climate Outlooks in Support of Sustainable Development (with the Third National Meteorological Conference of the Royal Meteorological Society, also at UEA, from 1–5 Sept.). To register your interest, please contact Dr John Turnpenny, Tyndall Centre, UEA, *phone: +44 (0) 1603 59 3908; email: j.turnpenny@uea.ac.uk.*

Climate change in the UK

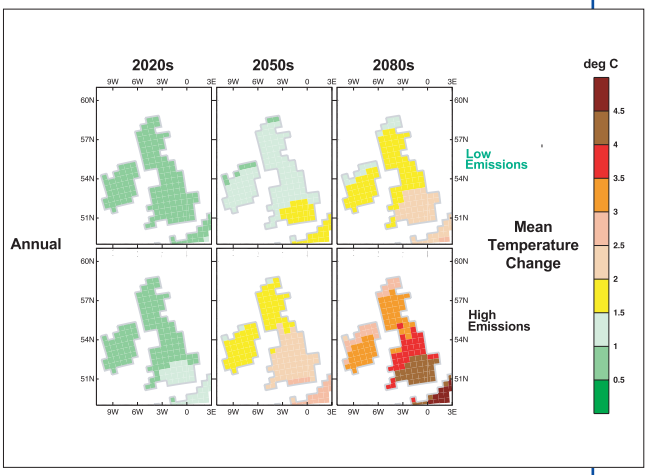
Over the coming decades, high UK summer temperatures will become more frequent, winters will become wetter and sea level will continue to rise around most of the UK's shoreline. These are some of the conclusions of the UK Climate Impacts Programme (UKCIP) 2002 climate change scenarios, launched in April. The set of climate scenarios, based on new model results from the Hadley Centre, were prepared by Tyndall Centre researchers under contract to DEFRA for the UK Climate Impacts Programme.

The UKCIP02 scenarios present four descriptions of how the world may develop in decades to come, based on four emission scenarios from the IPCC. It is not possible to say which scenario is most likely, as this is dependent on the future choices made by society.

By the 2080s, the average annual temperature in the UK may rise by between 2°C for the Low Emissions scenario and 3.5°C for the High Emissions scenario. A very hot August, such as experienced in 1995 may occur as often as three years in five by the 2080s.

For the High Emissions scenario and in the south and east of the UK, summer precipitation may decrease by 50% or more by the 2080s and winter precipitation may increase by up to 30%. Snowfall amounts will decrease throughout the UK. Sea level may be between 26 cm and 86 cm above the current level in south-east England, and extreme sea levels could occur between 10 and 20 times more frequently by the 2080s.

The described range of plausible futures aims to raise awareness of regional climate change, explore the implications of our decisions affecting future emissions, and assist in planning. The scenarios represent a major step forward in understanding how climate may change across the UK over the 21st century, and for several years to come will be the definitive description of future UK climate.



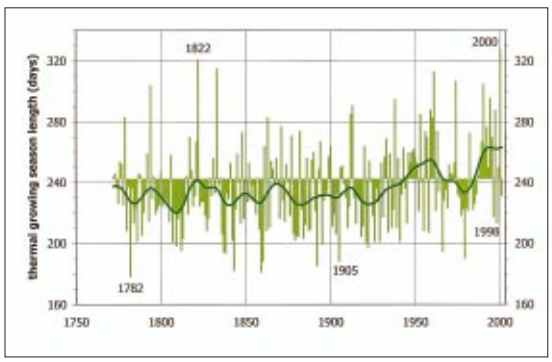
An example of the resolution given in the UKCIP02 report: mean temperature change in summer for the 30-year periods centred on 2025, 2055 and 2085, for two emissions scenarios.

Copies of the report are available online (www.ukcip.org.uk/scenarios) or by contacting the UK Climate Impacts Programme email: enquiries@ukcip.org.uk phone +44 (0)1865 432 076.

Growing season growing

Climate change is increasing the period of year in the UK when plants grow. Tyndall Centre researchers based at the University of East Anglia have found the thermal growing season is beginning earlier and finishing later. "If the trend continues, it is possible that we will have a year-round growing season within a generation," says Dr Tim Mitchell.

The longest growing season in the 229-year Central England Temperature record occurred in 2000. It began on 28 January and ended on 22 December, lasting 330 days. The results also show growing season has increased on average by more than a day a year over the last 20 years, with a 28-day increase since 1900. The increase has been due mainly to the earlier onset of spring, with some contribution from the later onset of winter.



The length of thermal growing season over Central England. Climate change is causing a longer growing season in the UK.

Dr Mitchell and Professor Mike Hulme define the growing season as starting when the daily average temperature is more than 5°C for five consecutive days, and ending when there is a run of five days below 5°C. The results appeared in the UKCIP02 report (see above) and were published in the May 2002 issue of the Royal Meteorological Society's journal, *Weather*.

Climate observations and future trends available by country

Social scientists, economists and other researchers with a particular interest in climate change within specific political borders can now access twenty-first century climate data and graphics for individual countries (www.cru.uea.ac.uk/timm/climate/countries.htm).

The Tyndall Centre dataset provides a summary of the temperature and precipitation changes that may be experienced during the twenty-first century in 289 countries and territories. An earlier dataset is also available, covering average climate in the recent past (1961-1990) and climate trends over the twentieth century (1901-1998).

Society must consider options to mitigate climate change . . .

Low carbon transport futures

Tyndall researchers are exploring ways to reduce society's reliance on motorised transport, which contributes nearly a quarter of the UK's carbon dioxide emissions and is forecast to rise. Dr Miles Tight, a University of Leeds researcher, says the Tyndall project's unique focus is on human adaptation, rather than other ways of reducing emissions such as improving vehicle efficiency or using renewable fuels.

Miles Tight (right) and colleagues at the Institute for Transport Studies are assessing ways households can adapt to achieve significant reductions in carbon dioxide emissions from passenger cars.

Miles and his colleagues determined realistic contributions transport can make to emissions reduction targets. They will now generate 'cartoon strategies' – outlines of ways to meet the targets by changing behaviour. The strategies include reducing travel distances through improved telecommunications and land use planning, investing in public transport, encouraging cycling and walking, or even introducing fuel rationing and road charges. "These strategies have been discussed in the past to reduce air pollution and congestion, but climate change may become the major driver for their implementation," says Miles.

But how willing are we to let go of car dependency? Having refined the strategies in consultation with transport experts and the general public, the research team will interview households to determine how the strategies would affect their lives. "We may find the message is that people can't cope with major reductions in car use, which will be important information in planning for greenhouse gas emissions reductions," says Miles.

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Environment Minister Michael Meacher inspects Mike Hulme's petrol-electric hybrid car, part of Mike's personal goal of reducing his lifestyle's carbon dioxide emissions by 60%.

A personal carbon reduction target

The Executive Director of the Tyndall Centre has put his lifestyle where his science is by purchasing a petrol-electric hybrid car.

Far from being a sacrifice, Professor Mike Hulme says his Toyota Prius will eventually save him money. With greater fuel efficiency than a conventional petrol or diesel car, the hybrid reduces expenditure as well as emissions. "At the time of purchase, the Prius was about £3000 more than a similar sized car," he says. "But with the Government's Powershift rebate of £1000, reduced annual tax and many more miles to the gallon, I've calculated that after five years I'll be saving money."

The Prius featured at the launch of the Tyndall Centre in November 2000, transporting the Environment Minister, Michael Meacher, from the train station to the University of East Anglia as an example of the type of climate change solution to which the Tyndall Centre is committed.

The Toyota Prius – and the other commercially-available hybrid car, the Honda Insight – looks and drives like a conventional car. The petrol engine kicks in when acceleration or power is needed, and also generates electricity to power the electric motor. Electricity is also drawn from the frictional energy of the wheels during braking and deceleration. The hybrid also reduces noise pollution, especially in heavy traffic.

The road to a hydrogen energy infrastructure

Hydrogen is probably the leading alternative fuel for cars, aircraft and domestic heat and power in the twenty-first century. Political and private sector interest in hydrogen has recently increased dramatically. However, further technological advances and political changes are required before the UK's infrastructure could support a large-scale hydrogen energy economy.

Dr Geoff Dutton, from the CLRC Rutherford Appleton Laboratory's Energy Research Unit, is leading a Tyndall project to map out the stages required for a national energy infrastructure based on hydrogen produced from renewable sources. Unlike fossil fuels, molecular hydrogen does not exist naturally in large quantities on Earth and must be made from other fuels. It can be chemically separated from hydrocarbons using a reformer (at which stage the carbon dioxide can be collected for sequestration), manufactured biologically via photosynthesis or ermentation, or by electrolysis of water. If the electricity for electrolysis is derived from renewable sources, carbon emissions are truly zero because water is the only combustion by-product.

The Tyndall project brought together representatives from power regulators, industry and academia to discuss the technologies and policies required to facilitate the transition to a hydrogen energy economy. The researchers now aim to establish the benefits (and potential limitations) of widespread hydrogen energy use, and define the stepping stones required to achieve this long-term goal. The results will be delivered as a set of detailed, quantified scenarios for the development of a hydrogen economy in the UK.

© DaimlerChrysler

Hydrogen fuel is already used in a small number of demonstration projects but the costs of producing and storing hydrogen prevent it being used more widely. A Tyndall project is investigating how to introduce a hydrogen energy economy to the UK.

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Can Britain adapt to climate change?

Climate experts and a panel from the water, construction, insurance and energy sectors led a discussion forum during National Science Week 2001 on the challenges of climate change for UK businesses. Other representatives from these sectors, Government officials, MPs, scientists, and non-governmental organisations, contributed to a lively discussion about mitigation and adaptation. The event, hosted by the DTI in London, was organised by NERC, ESRC, EPSRC and the Tyndall Centre.

A full report on the discussion is available at: *www.tyndall.ac.uk/events/past_events/dti_210301_full_report.shtml*

the effect: cutting back on your transport emissions

Global transportation contributes 21% of the greenhouse gas emissions from human activities. Consider ways you can make a personal contribution to reductions:

Investigate the UK Government's Energy Saving Trust Powershift programme (www.est-powershift.org.uk) which provides financial support towards the purchase of gas, electric and hybrid vehicles.

Make your car journeys more worthwhile by planning and combining visits.

Drive more smoothly and service your car regularly.

Think about walking, cycling or using public transport: call your local bus or train company to ask about routes.

Use car-pooling where possible: many regions now have Websites to facilitate this (e.g. www.liftshare.com or www.carshare.to).

Explore your own country on holidays before flying to far-flung destinations.

Consider a fuel efficient vehicle as your next car, such as a petrol-electric hybrid.

Consider living closer to work when you next move home.

The Tyndall Centre is working on new suggestions for carbon emission reductions from transport on a national scale (see pages 6-7).

. . . by reducing emissions from transport, energy generation and industry . . .

Integrating Renewables into the UK electricity system

The introduction of the Renewables Obligation in April 2002 marked the next stage in the Government's plan to meet 10% of UK electricity demands from renewables by 2010. Every energy supplier must produce certificates proving a set percentage of their electricity has come from renewables, or otherwise buy certificates from energy suppliers with a surplus of certificates.

The Renewables Obligation in theory should attract large numbers of investors into the renewable energy market, but in practice could be far from perfect. "Tyndall Centre projections suggest the Renewables Obligation could boost the value of renewable electricity by up to 5.5p per kWh more than the 2002 market electricity price of around 1.6p per kWh," says Dr Jim Watson of SPRU and the Tyndall Centre in a report with Dr Adrian Smith. "The question is, will this revenue boost overcome the hurdles of planning, network access and electricity trading rules that are holding renewables back?"

© Vestas Wind Systems A/S

Tyndall Centre researchers welcomed the Renewables Obligation as a step towards meeting the Government's target of obtaining 10% of the UK's electricity from renewables by 2010. But with renewable energy currently supplying just 3% of our electricity, other policies need to support the Renewable Obligation to stimulate innovation and bring forward the next generation of renewable energy technologies.

The authors also say that while the new Renewables Obligation and other policies are providing welcome support for renewable technologies, further incentives are required to stimulate innovative new electricity supply systems. "A portfolio of competitive renewable technologies is not sitting waiting to be taken off the shelf, plugged in and put to use like a new washing machine," says Jim.

He says there are a number of challenges confronting the Government's plan to more than triple renewable energy capacity by the end of the decade. For example, the difficulty of obtaining planning permission can prevent the development of new renewable energy projects, particularly wind energy schemes, and the New Electricity Trading Arrangements (NETA) favour conventional generators over renewables, sometimes rendering unpredictable sources such as wind practically worthless.

NETA had a potentially devastating effect on the value of wind power in the UK in its first week of operation, say other Tyndall researchers who analysed energy prices and wind energy outputs. Their results show that a wind farm would have made a loss selling electricity to the grid. NETA, introduced in March 2001, requires suppliers to forecast the amount of energy they will supply 3.5 hours ahead of delivery. "The most profitable way of operating a wind farm was to turn it off," said Professor Goran Strbac, a Tyndall Centre researcher based at UMIST. "Due to the intrinsic difficulty of forecasting available winds and other sources of renewable energy, these suppliers are likely to suffer under NETA," he said. The energy regulator, Ofgem, says renewables are no longer suffering disproportionately, following reforms to NETA such as a shortened forecast period from 3.5 to 1 hour. However, a House of Commons Committee has recently concluded that more needs to be done.

A number of challenges confront the UK Government's plan to more than triple renewable energy capacity by 2010. Electricity network operators and regulatory authorities are not giving equal treatment to small renewable energy generators, often making it prohibitively expensive for them to connect to the national electricity network.

Jim, Goran and other researchers with the Tyndall Centre are working on the Tyndall project 'Integrating Renewables into the UK electricity system', which will be completed in late 2003. They are investigating the technical and regulatory improvements required to allow the use of smaller, low carbon energy sources, which aim to pursue climate change objectives.

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Tracking Tyndall emissions

The Tyndall Centre is measuring emissions of carbon dioxide arising from work-related travel. Since October 2001, Tyndall headquarters staff and other individuals involved in centrally organised Tyndall events have noted approximate mileage for all UK and overseas conferences, committee meetings, seminars, etc. Emissions per mile are then calculated by applying conversion factors for different modes of transport. Over the first nine months, Tyndall Centre staff travelled more than 180 000 miles by air on business trips, accounting for nearly 90% of our 19 metric tonnes of work-related travel carbon emissions. The scheme is the first step towards setting and achieving an annual target to decrease carbon emissions resulting from travel by encouraging staff to use lower-carbon alternative modes of transport.

Microgrids: power generation at home

Small energy sources integrated into buildings would reduce electricity transmission losses, improve reliability of supply and could provide heating as a by-product. If such onsite generators were fuelled by sources such as sunlight or small wind turbines, they would also decrease greenhouse gas emissions.

Dr Peter Wilson, a Tyndall researcher based at the University of Southampton, says reducing the system's size makes it more practical. “The power source needs to pass what I call the DIY test: it must be obtained easily and inexpensively, and be able to be installed in a home without any problems,” he says.

Peter has designed an intelligent fuse box to automatically choose where power for the home comes from. The intelligent fuse box stores information such as electricity rates and peak energy use in the home, then improves energy and economic efficiency by switching between utility-supplied power, the onsite generator, and a battery. He is now testing a virtual prototype using UK weather data to determine the optimum configuration for various generator types, including solar, wind and domestic combined heat and power.

Peter says his intelligent fuse box is a useful way to reduce emissions from electricity generation. It could even be scaled up to control microgrids in housing estates or shopping centres. “This could make things practical,” he says. “If an idea is purely academic, it's not useful in this field.”

Peter Wilson (left) and Tom Markvart are investigating the technical and economic issues of using small electricity networks (microgrids).

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Reducing carbon locally

Several local authorities are leading the way on low-carbon sustainable energy, but activities are restricted by an unresponsive policy framework and an inability to measure carbon emissions locally. These are some of the findings of a review led by the Tyndall Centre's Dr Simon Shackley at UMIST, completed for the Sustainable Development Commission.

The research team interviewed more than 70 people from local, regional and national government, NGOs, voluntary groups and the private sector to document carbon-reduction activities at different scales. They also compiled an inventory of 100 low-carbon success stories.

“All local authorities have undertaken energy efficiency measures as part of estates and housing management,” says Simon. “But they have limited ability to use the planning system to reduce the carbon intensity of developments because they don't have the power to reject planning applications on the basis of high carbon emissions.”

© Bill Dunster Architects

Although some local councils are leading the way on reducing the carbon intensity of development, centralised UK energy responsibility reduces the incentives and resources to encourage energy efficiency measures at the local scale.

He says a dozen or so local authorities have led the way, thanks to committed council members, in-house energy specialists and partnerships with private, public and NGO sectors. However, he says it is virtually impossible to monitor the effectiveness of policy measures due to an inability to measure carbon emissions at the sub-UK scale.

“Actions at the local to regional scale are needed to deliver extensive carbon emission reductions, but to date most strategic thinking has focused on national mechanisms,” says Simon. “There is great untapped potential for bottom-up led carbon reduction.”

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. . . and finding new ways to sequester carbon through safe storage.

Where will we be in 50 years?

Professor Ken Green and other researchers at UMIST are developing a set of scenarios describing how technological change may affect global energy demand over the next 50 years.

"Technological change, industrial change, energy demand – and therefore environmental change – are intimately connected," says Ken. "We are trying to describe the key interactions between sectors within the economy."

Drawing on many theories of long-term technology diffusion and the futurology literature, Ken says that biotechnology has the potential to influence a range of industries, including medicine, agriculture, materials technology and environmental monitoring. Such developments will continue to be assisted by advances in information technology. Nanotechnology could lead to major advances in computing power, which would in turn push biotechnology forward. "Technological developments over the next few decades will be concerned with information manipulation, and manipulation at the molecular level of organisms and materials," he says.

However, these will develop at different rates. "Manipulation of information will be routine and embedded in all activities by 2025, just as electric motors are used routinely in devices filling homes and cars today." He says biological manipulation will not have significant effects on the structure of industry until after 2010 and that – contrary to hype – the effects of nanotechnology on industry will not be felt until at least the mid-2020s.

Technological change is a key driver of economic development, so such predictions are needed for economic models. The project contributes to a Tyndall project developing long-term, global economic models to analyse energy production and climate change.

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The 40% house

UK households need to achieve a 60% reduction in their carbon dioxide emissions by 2050 if we are to avoid significant climate change. A new Tyndall project is identifying immediate actions that will reduce energy demand in homes.

Dr Brenda Boardman, from the University of Oxford's Environmental Change Institute, will interview households to determine the choices people are willing to make to save energy. They will also investigate how heating and cooling demand will be influenced by climate change.

The project involves laboratory tests on home appliances to investigate ways to avoid peaks in energy demand. "We need to identify the crucial policies to be implemented now, such as setting new standards for energy use by appliances," she says.

They will use computer models of different house types to investigate ways for homes to obtain energy from new and renewable sources. Leading by example, Brenda and another researcher working on the project use solar thermal to heat hot water and also buy green electricity. Another Tyndall researcher, Tyndall North's Dr Kevin Anderson, has also minimised his energy use by extensively remodelling his house in Manchester, and installing a diesel TDI engine and a fuel efficiency device in his campervan.

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Homes use nearly a third of the UK's energy, so individuals can play a huge role in reducing greenhouse gas emissions. Globally, the generation of electricity is responsible for 30% of greenhouse gas emissions. Improving the energy efficiency of your home contributes to national emission reduction targets:

Improve the energy efficiency of your home by draft-proofing doors and windows, and improving insulation. Investigate the availability of rebates for energy-efficient home improvements (e.g. www.est.co.uk)

Turn off lights in rooms you are not using and turn off appliances such as the television at the mains switch rather than leaving them on stand-by.

Replace old light bulbs with energy-efficient bulbs and consider other ways to save energy (e.g. www.saveenergy.co.uk)

Change to an electricity supplier that generates or obtains electricity from renewable sources (e.g. www.greenenergy.org.uk).

When buying a new appliance, let the energy efficiency rating influence your choice. Buy an insulating jacket for your hot water boiler or consider buying a new, energy-efficient boiler.

The Tyndall Centre is working on new ways to reduce carbon emission from electricity production at household level, and on a national scale such as by improving the connection of renewables to the UK energy grid.

***the effect:* cutting back on your home energy emissions**

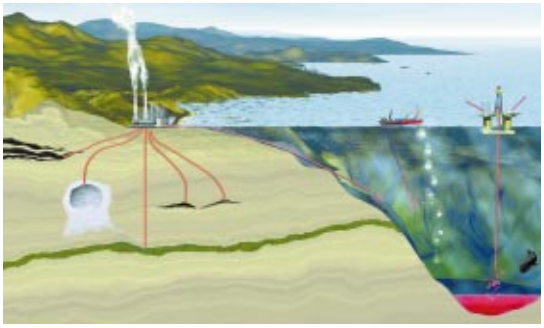
Burying carbon

Early results from a Tyndall project suggest that removing carbon dioxide from power stations and storing the carbon underground is seen as an acceptable short-term response to climate change.

"Before renewables can make a sufficently significant contribution in the long-term, large and reliable reductions in carbon dioxide emissions in the UK may come to a choice between nuclear power or carbon storage," says Clair Gough, a Tyndall researcher based at UMIST. "The potential of UK offshore storage in oil and gas fields and deep saline aquifers equates to many decades of all UK emissions." However, while the storage capacity is high, currently it is only possible to capture emissions from large sources such as power plants.

Carbon can be stored in geological structures or disused oil and gas fields deep below the ground or sea floor. Carbon dioxide has been removed as gas is produced from a field off the Norwegian coast since 1996, storing a million tonnes of carbon dioxide each year in a saline aquifer.

Focus groups and specialists interviewed by Clair in a pilot study saw geological sequestration as a potential solution to climate change if the carbon could be locked up for thousands of years. While stressing the results are preliminary, Clair says those interviewed saw geological sequestration as a possible bridging policy while longer-term solutions are developed. The researchers are now working with geologists, lawyers, engineers, environmental scientists and economists to look in more detail at the long-term effectiveness, economic viability and social acceptability of specific geological sequestration sites.



© David Firstan

Carbon dioxide can be pumped to storage areas underground and beneath the sea floor. Tyndall researchers are examining the effectiveness, viability and acceptability of geological sequestration.

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Business and climate change

A Tyndall project has revealed that climate change will affect businesses in ways often not evident to the companies themselves. Researchers interviewed companies in the UK house building and water service industries to assess how they can protect themselves from climate change risks and make the most of new opportunities.

Julia Hertin (left), Dr Frans Berkhout and other SPRU researchers have established links with house building and water service industries. Their Tyndall project has investigated how companies could respond to the effects of climate change.

Julia Hertin, one of the project researchers based at SPRU, says the interviews identified a wide range of adaptation measures considered by businesses. "The building industry has little awareness of the need to adapt to risks such as flooding, while the water industry already views climate change as an important part of their business," she says. "We've also found that indirect impacts such as rising insurance premiums or tighter regulation could be more significant than direct climatic effects." As well as having to adapt in the face of uncertainty about future climate, businesses must make decisions within constraints such as customer demand, regulations, information availability and technological capacity. "We have to put in place the right incentives for adaptation, otherwise everybody may just try to pass on the risks to the next person," says Julia.

From information gathered through interviews, the researchers have built an inventory of climate change impacts faced by the house building and water service industries and ways in which they could respond. For comparison, they will now conduct interviews with similar organisations in France. Their aim is to develop practical tools to enable firms to assess and improve their capacity to adapt to climate change.

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Tips for organisations, business and councils:
Climate change is happening, will continue and has both negative and positive impacts. Scientists predict a range of future climates to help plan and reduce risks (see page 5). Organisations and businesses should:
Conduct a climate change audit for any decisions sensitive to weather and climate that has a life-span of more than 10 years: will climate change undermine the investment, does infrastructure allow for climate change?
Consider energy conservation and incentives: is energy efficiency encouraged in future buildings through assessment of planning applications?
Track developments in energy policy: areas where technology is promising but currently commercially unattractive may become more viable.
Identify projects that combine carbon reduction with climate change adaptation: e.g. plant trees or energy crops on flood plain areas.
Plan for opportunities through a cost-benefit analysis of options: e.g. protecting against sea level rise by creating wetlands could enhance the coastline's value through tourism.
Introduce an annual carbon audit to see how much your activities contribute to carbon emissions and from where.
Appoint a climate change education officer for internal and external awareness: e.g. display board of carbon dioxide emissions saved as a result of actions; local information on Web site.

Designing buildings for extremes

Buildings constructed today will need to cope with higher summer maximum temperatures, more sunny days and increased humidity in the coming decades. Such changes in climate must be considered when designing buildings to ensure they are comfortable for inhabitants.

© M.Robinson

Buildings constructed today could last into the twenty-second century, so must be designed to cope with future extreme weather. Tyndall researchers are generating future weather data for the building industry to test how climate change will affect comfort and energy use in buildings.

Researchers at the Tyndall Centre are compiling hourly weather data for 2025 and 2050 as test reference years for the building industry to assess future building performance. "With climate change occurring, designs based on historical data will produce uncomfortable summer thermal conditions in buildings," says David Chow, a member of the research team based at UMIST. Together with researchers at the Climatic Research Unit, he has used daily climate simulations from the UK Met Office's Hadley Centre, comparisons with hourly observations, and the statistical properties of weather extremes to generate the weather data for 2025 and 2050. He is now testing the data to ensure they provide useful descriptions of future climate.

The researchers are also developing programmes that use weather data to test features such as passive solar design, smart shading and enhanced natural ventilation to assess building performance in future extreme weather conditions, primarily in South East England

The hourly temperature, solar radiation, humidity and wind data for 2025 and 2050 will be available on CD in 2003.

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Climate change as a security issue

For some societies, climate change poses risks comparable to the impacts of war, says a Tyndall Visiting Research Fellow. However, he says that countries have never, nor are likely to, go to war over environmental issues, even when water catchments cross international boundaries.

Dr Jon Barnett, who visited the Tyndall Centre during 2001 from the University of Canterbury, New Zealand, says climate change and sea level rise put at risk the ability of people to remain living on low-lying islands. "In this respect it is the most serious security problem that these countries face. Nothing less than their sovereignty is at risk." He says climate change is also a security issue for certain cultures, for example by reducing hunting grounds for Inuit communities, and increasing vector-borne disease risk to people in the highlands of Papua New Guinea.

However, factors such as availability of resources and weapons contribute more to violent conflict than environmental change. "On the basis of existing environment-conflict research there is simply insufficient evidence to make anything other than highly speculative claims about the effect of climate change on violent conflict."

Jon says if climate-induced conflicts are to occur at all, they are most likely to be a result of mass migration. "To avoid the subsequently enhanced risk of violent conflict, slowing the rate of climate change by reducing greenhouse gas emissions, and enhancing adaptive capacity to changes in extreme weather events is essential."

Climate change poses risks comparable to war; for example, sea level rise threatens the sovereignty of small island nations. It could also exacerbate internal conflicts in weak states. However, it is unlikely to lead to international conflict.

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Follow a fellowship

International (non-UK based) researchers can tap into the funds available through the Tyndall Visiting Fellowship Programme. This encourages intellectual and institutional collaboration by allowing outstanding international researchers to work with the Tyndall Centre on inter-disciplinary research projects related to climate change. Fellowships awarded to date include Dr Jonathan Barnett's visit to UEA (see above); Dr John Latham (NCAR, Colorado) is visiting UMIST to assess the feasibility of compensating for global warming by enhancing the reflectivity of maritime clouds; and Janaka Ekanayake (University of Peradeniya, Sri Lanka) is visiting UMIST to explore how climate change is likely to impinge on the Sri Lankan power grid system. Full details are available online (www.tyndall.ac.uk/research/visiting_fellowships/vf.shtml).

Climate change disrupts emergency services

Extreme weather events are hindering the ability of the Fire Service to respond to emergencies, says a PhD student affiliated to the Tyndall Centre. "At the frontline, the Fire Service is having to deal with the results of this meteorological mayhem," says Dorian Speakman, whose research focuses on flooding in North Yorkshire. "They have to rescue people, pump out water or stabilise wind damaged buildings."

© Yorkshire Post

More warning is needed so emergency services can plan resources to respond quickly to severe weather events.

Dorian says a pattern of disruption is definitely emerging. "By analysing response times during severe weather events, disruption becomes apparent as the number of call outs increase and response times are way above normal," he says. His results were confirmed by interviews with local emergency services, who told Dorian of disruption due to routes being cut off and stretched resources. However, he points out that call outs to fires are a priority and have not been disrupted.

Dorian is completing his PhD at UMIST, supervised by the Tyndall Centre's Simon Shackley, with funding from NERC and ESRC. He says the last two years have been a watershed for emergency planning, following widespread floods, rail crashes, foot and mouth, and terrorism. Although climate change is also being considered in emergency service plans, more information is needed. Dorian is relating geographical patterns of emergency service hindrance and the types of weather systems that cause the most disruption, to availability of emergency services and the community's state of preparedness. His aim is to provide information to help plan and prepare for emergencies in an uncertain future.

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Tyndall consortium websites

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Southampton Oceanography Centre: www.soc.soton.ac.uk
UMIST: www.umist.ac.uk
Energy Research Unit at RAL: www.eru.rl.ac.uk
SPRU — Science and Technology Policy Research: www.sussex.ac.uk/spru
The Institute for Transport Studies at Leeds University: www.its.leeds.ac.uk
University of Cambridge: www.cam.ac.uk
Centre for Ecology and Hydrology: www.ceh.ac.uk
Cranfield School of Management: www.som.cranfield.ac.uk/som/complex

Tyndall postgraduate research

The Tyndall Centre has awarded a number of co-funded research studentships:

- Sebastian Carney (UMIST) is creating a regional greenhouse gas inventory for the northwest and is investigating mitigation options, in collaboration with Environment Agency Northwest;
- David Chow (UMIST) is examining how to adapt the design of naturally ventilated buildings to account for climate change in the UK, in collaboration with Hoare Lea Consulting Engineers;
- Allison Colls (UEA) is addressing the obligations of conservation organisations in terms of carbon sequestration and biodiversity, in collaboration with English Nature;
- Joy Aree Kim (UEA) is carrying out a case study of integrated policy-making in South Africa to investigate the linkage between climate change and trade policy, in collaboration with Shell International;
- John McWilliams (UEA) is investigating the implications of climate change for biodiversity in the UK overseas territories, in collaboration with the Joint Nature Conservancy Council;
- Lisa Schipper (UEA) is exploring policy responses to facilitate adaptation to climate change in developing countries, in collaboration with the University of El Salvador;
- Petar Varbanov (UMIST) is evaluating the design of industrial utility systems for cost-effective reductions in carbon emissions, in collaboration with Process Integration Research Consortium.

The Tyndall Centre is also supporting other postgraduate students working on Tyndall research projects or on closely relatedtopics. Details of these projects, and information on how to apply for a Tyndall Research Studentship, are available on our Website (www.tyndall.ac.uk/research/research_studentships/rs.shtml).

The Tyndall Centre aims to motivate society to choose our future climate . . .

Climate change and tourism

Tourism is the most important source of employment and revenue on some Caribbean islands, with about 15 million visitors flocking to the region each year for pristine beaches, clear seas and colourful coral. But the attributes desired by tourists are threatened by sea level rise, precipitation and high temperatures. Maria Uyarra, an MSc student at UEA, investigated what tourists valued on the islands of Barbados and Bonaire. Her results confirm that visitors to the islands have different priorities:

How much would you pay? A Tyndall project surveyed what people valued on Caribbean islands, if they would still visit islands degraded by climate change, and if they were willing to pay to protect them.

Barbados attracts people looking for beach holidays; in Bonaire people come to dive in waters thriving with marine life. Visitors to both islands value warm temperatures and clear seas.

However, Maria found that climate change impacts could stop the tourist flow. "In Barbados, 81% of tourists said they would not come if beaches disappeared due to sea level rise, while in Bonaire it was coral bleaching that would keep 80% of tourists away," she says. "They would only come if the holiday was cheaper, or some would not come at all."

This led Maria to enquire how much tourists were willing to pay to ensure the holiday lived up to expectations. On both islands, people were willing to pay an average of about US$11 extra a night to protect coral reefs. To protect beaches, people on Bonaire

Photos © Maria Uyarra

Maria interviewed nearly 1000 people in hotels, airports, diving shops and even on the beach.

were only willing to pay US$6 extra a night, whereas on Barbados the figure was more than twice this amount.

The results suggest priorities for adaptation policies and contribute to the Tyndall Centre's project examining climate change impacts on Caribbean islands.

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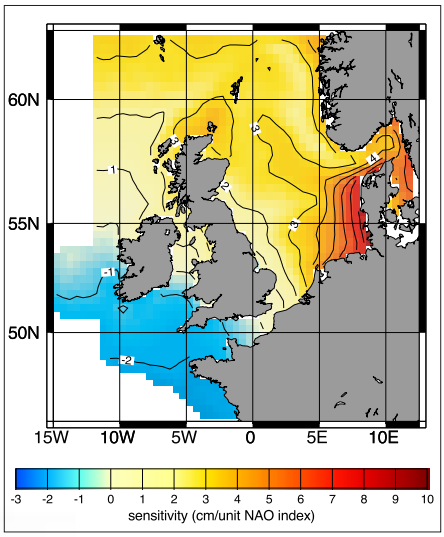
How vulnerable is the UK coastline?

A meteorological pattern influencing temperature, precipitation and wind over Europe also has an important influence on sea level and wave height around the British Isles and continental Europe, Tyndall researchers have confirmed. The results will improve estimates of sea level rise due to climate change and assist in assessing coastal vulnerability.

Mikis Tsimplis (centre) and colleagues have used satellite measurements and tide gauge records to show seas have risen due to the North Atlantic Oscillation.

When the North Atlantic Oscillation (NAO) index is positive in winter, strong westerly winds bring higher temperatures and increased precipitation to the UK. Dr Mikis Tsimplis, from the Southampton Oceanography Centre, says it has lately altered the pattern of sea level variability around the coast and increased wave heights. "The NAO in winter has switched from negative in the 1960s to almost continuously positive values during the last three decades," he says. "Thus it is evident that the NAO has and will continue to play an important role in coastal vulnerability."

Mikis says the influence of the NAO was shown from tide-gauge measurements extending back 200 years, a decade of satellite-based altimeter measurements, and from computer models. The research team will now use the projected changes in sea level and wave height to estimate changes to the coasts of three focus



The change in winter sea surge elevation resulting from increases in the North Atlantic Oscillation. For example, an increase in the NAO index of 3 means an increase in surge height of 3-6 cms on the east coast of England, but an increase of 24-27 cms at the east North Sea.

areas in south England, East Anglia and northwest Scotland. They are working closely with stakeholders to see how changes in sea level, wave height and coastal shape will affect coastal economies.

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Seeing the future

Tyndall researchers at UEA are harnessing the technology of computer games to help planners make crucial decisions. Dr Andy Jones is developing virtual reality environments that graphically show how future coastlines could be affected by climate change. By 2004, planners could use these computer-generated fly-past videos and photo-real images as part of the decision-making process.

Andy says the virtual reality system will be a vast improvement on current methods of informing people of planning decisions, which use two-dimensional maps or complicated technical documents. “Within two years we will be able to visit communities with a laptop computer projecting a future version of their town on a 6-foot wrap-around screen,” he says. “It will give people the freedom to walk around in virtual reality and explore the effects of climate change and the impacts of various decisions that will need to be made to protect the coast.” People will also be able to explore the virtual environments through the Web or in new virtual decision theatres being built in the new ZICER building (see page 4).

For example, a local council could see how their coastal region would look if they took no action, in which case the beach could appear eroded. They could then view the environment as it would look if protected by sea walls, and view it again as it would appear following a decision to allow a controlled breach of the dunes.

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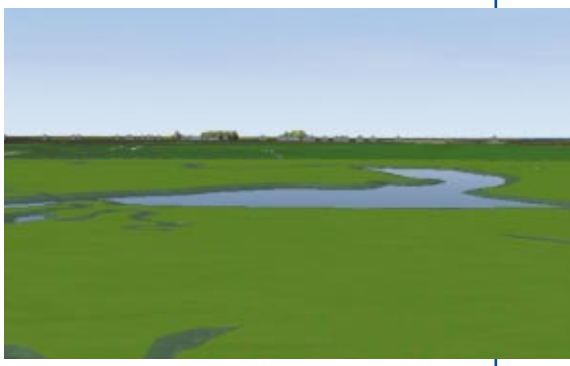
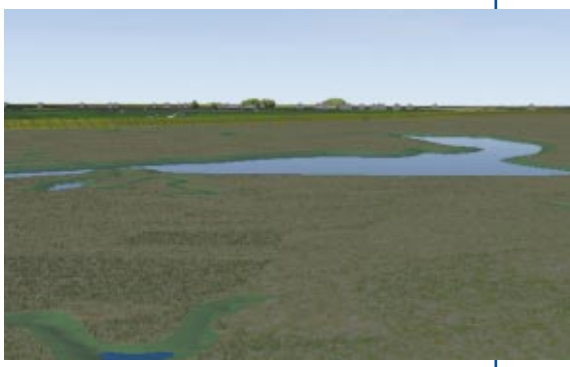


A Tyndall Centre project is investigating how people interpret and react to information about the effects of climate change presented as a virtual environment. The system will initially be tested on the low-lying Norfolk coastline around Holme-next-the-sea, as depicted in these images of Holme today (above) and as it could appear in future following dune erosion and reversion to salt marsh.



Art and climate change

The Tyndall Centre has appointed an ‘artist-in-residence’ to produce work about future climate change, in collaboration with the Norwich School of Art and Design and with funding from the Calouste Gulbenkian Foundation. The project aims to use art inspired by climate change research to reach audiences who may not otherwise discuss the issue. The selected artist is Janice Kerbel, whose past work has included the authoritative and credible depiction of fiction: a book detailing how to rob a London bank, a Website promoting an island paradise (www.bird-island.com) and the images and sounds of bird life on the fictional island.

Janice’s work will investigate the notion of ‘ideal conditions’ (for both plant and human life), the ‘closed environment’ (as a paradoxical model for the future), the political nature of desire and the delicate balance between culture and nature. The art will bring climate change into focus to show how it influences and is influenced by people’s daily lives. As a result, audiences will consider how their behaviour influences the global climate, form opinions about the threats and urgency of climate change, and possibly change behaviour to tackle its causes.

Artist Janice Kerbel, whose previous work includes the depiction of a fictional island and its bird life, is working with Tyndall Centre scientists to produce work inspired by climate change research.

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Vulnerability to past weather disasters

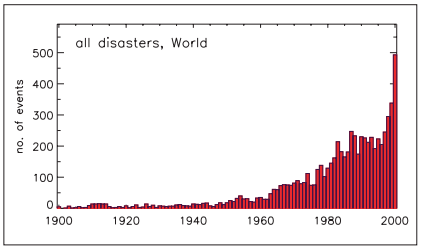
Small island states and some developing nations have been the most vulnerable to climate variability in the past, says a Tyndall researcher. "The principal manner in which climate change is likely to manifest itself is through increases in the frequency and severity of certain extreme events," says Dr Nick Brooks, from the Tyndall Centre and UEA. "Some countries are historically more vulnerable than others. We can learn important lessons from this for adaption to future climate change."

A Tyndall project is developing national indices that represent countries vulnerability and capacity to adapt. This will help identify regional climate impacts and set priorities for adaptation.

Nick obtained data about recorded frequency of extreme events to assess exposure to climate hazards in the twentieth century and estimate the risk posed to a country by climate variability and change. He found incidences of floods, windstorms, epidemics and landslides exhibited striking upward trends. While acknowledging it is difficult to say if the trends are due to increased weather extremes or better reporting, he says it is probable that the increased frequency of recorded disasters results from socio-economic and demographic changes, with some contribution from climate change.

"Changes within a society may reduce its ability to cope with an environmental perturbation, making it more vulnerable to events that are relatively common and leading to a natural disaster," says Nick.

The climate sensitivity results will be combined with economic measures and information about aspects such as health and social co-operation. The Tyndall project led by Dr Neil Adger aims to quantify a country's vulnerability to climate change and its capacity to adapt to the impacts. The researchers have already provided input into United Nations guidelines on how countries can assess adaptation needs and potential.



An aggregate of all disaster types shows an upward trend interrupted by a slight decline from the late 1980s to late 1990s.

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ECF European Climate Forum

The Tyndall Centre is one of seven founding European research centres in the European Climate Forum (ECF), and Mike Hulme has been elected Chair of the ECF Council. The ECF is a non-profit organisation forging alliances between leading scientists, NGOs, industries and others to research and debate climate change challenges.

The scientific founding members of the ECF are the Tyndall Centre, Potsdam Institute for Climate Impact Research, Max Planck Institute for Meteorology in Hamburg, International Research Centre on Environment and Development, Paris, Fondazione ENI Enrico Mattei in Milan, Nansen Environmental and Remote Sensing Centre in Bergen and Paul Scherrer Institute, ETH Zurich. The ECF is open for institutions, businesses, other organisations and individuals: for membership send a request to Carlo Jaeger (email: info@European-Climate-Forum.net) and visit www.european-climate-forum.net for information about upcoming events.

Business liaison programme

The main objectives of the Tyndall Centre's Business Liaison Programme are to develop a partnership network of businesses and organisations affiliated to the Centre, to seek to inform the business community on the Centre's research and to identify and nurture opportunities for joint research and outreach projects. The programme is funded by the Department of Trade and Industry.

Some companies already consider climate change and its impacts in their long-term business planning and many more are preparing to do so. However it is clear that businesses need more information on both the impacts of climate change, and our ability to adapt and respond. The Tyndall Centre is committed to sharing research results and is disseminating our researchers' findings to business through briefings, a quarterly electronic newsletter, displays at key trade events and other communication activities.

We also offer visits and presentations by Tyndall scientists to provide further information and discuss opportunities for engagement. The Tyndall Centre already has working links with over 50 public and private sector organisations and is keen to encourage collaboration and open dialogue on climate change issues with other stakeholders.

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Tyndall scientist wins place in Whitehall

Dr John Turnpenny, based at the Tyndall Centre and UEA, won a placement in Whitehall to work with DEFRA officials developing policies to cope with climate change. He spent two months in summer 2001 at the then Department of the Environment, Transport and the Regions, helping evaluate various energy and development paths the UK could follow over the next few decades.

"For many years, governments and companies have used expert judgement and analysis to develop scenarios, or potential pictures of the future, to act as a basis for strategic planning," said John. "These give plausible estimates of future changes in, for example, economic performance, population patterns and climate, based on the latest insights." John's placement was part of a HM Treasury scheme called Summer Placements in Whitehall. The Government is keen to strengthen links with the research community and encourage its involvement in policy making.

Tyndall researcher John Turnpenny spent time in Whitehall advising Government on the use of climate change scenarios, as part of a programme to strengthen links between policy makers and researchers.

He reviewed how the Government uses scenarios in addressing the challenge of climate change. His work provided a guide for different groups wanting to use scenarios to aid their decision-making, such as town and land use planners, and regulatory authorities in the towns and cities.

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Policy-relevant and scientifically-innovative

The Tyndall Centre aims to exert a seminal influence on the design and achievability of the long-term strategic objectives of UK and international climate policy, stimulating the transition to a more benign energy and mobility regime. Tyndall researchers have therefore sought opportunities to interact with policy-makers on many occasions. For example, Tyndall researchers contributed advice to the House of Commons Science and Technology Committee's Third Report on Scientific Advice on Climate Change. To help inform discussion on flood and coastal defences, the Tyndall Centre assisted the Parliamentary Office of Science and Technology and the Environment Agency to organise a seminar at Westminster on managing flooding. More than 70 people attended, including MPs and researchers, academics, representatives from Government departments and flood groups.

The Tyndall Centre has also welcomed Parliamentarians to discussions at its offices. After launching the Centre in November 2000, Environment Minister Michael Meacher returned to Tyndall Headquarters with Norwich MPs Ian Gibson and Charles Clarke in May 2001 to be updated on the Centre's progress. In the same month, Dr John Taylor, the Director General of Research Councils in the OST, discussed climate change issues with Tyndall and UEA researchers. After the meeting, Mike Hulme reflected that Dr Taylor recognises the long-term nature of what the Tyndall Centre has embarked on and clearly wanted Tyndall to be ambitious, and is keen to see UK science make an impact on the European and world stages. Tyndall North and UMIST hosted a visit by Andrew Stunell MP, the Liberal Democrats spokesman on energy. Mr Stunell held discussions about research activities and ways for 50% of UK energy to be met by renewables including wind, solar and wave power.

Tyndall Centre researchers have held discussions with policy-makers on many occasions. With Environment Minister Michael Meacher at the launch of the Tyndall Centre are (from left) Mr Peter Hedges, Sir Anthony Cleaver, Professor Mike Hulme, Sir Geoffrey Allen, Dr Bruce Smith and Professor John Lawton.

Research Strategy

The Tyndall Centre Research Strategy describes the Tyndall Centre's main tasks and challenges, its purpose and objectives, and details of the research themes. A summary document and full strategy are available online at www.tyndall.ac.uk/research/strategy.shtml or you can obtain a printed version by contacting Vanessa McGregor (Email: V.McGregor@uea.ac.uk; phone 01603 59 3900).

We bring together climate scientists, social scientists, engineers and economists from academic institutions around the UK . . .

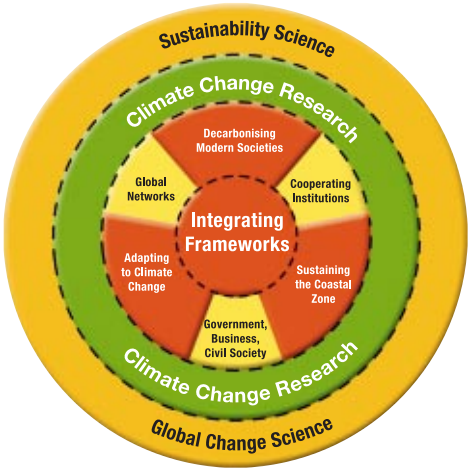
Focusing the Tyndall Centre's research

In its first year of operation, the Tyndall Centre has consolidated its research strategy into four research themes.

Research Theme 1 *(Integrating Frameworks)* brings together information from distinct disciplines and scales, and organises it into a coherent system needed for climate change decision-making. The integrating framework will be made up of representations of the main physical and socio-economic elements of the climate system. Ongoing interaction with stakeholders will identify relevant questions and check the usefulness of answers to feed back into the simulation system. Researchers will analyse the framework's validity, considering uncertainty and ensuring large errors are not propagated through the system. The research in this Theme will allow the exploration of how different choices affect future social, economic and climatic conditions at global and regional scales.

Research Theme 2 *(Decarbonising Modern Societies)* involves interdisciplinary assessments of ways to reduce emissions of greenhouse gases, and subsequently limit the increase in their atmospheric concentration. This will provide information to help achieve national and global emissions reduction targets. Technical, managerial and behavioural strategies leading to a 60% reduction in carbon dioxide emissions by 2050 involve many scientific, economic, social and political details that require in-depth evaluation. This work in Research Theme 2 will lead to an integrated assessment of the prospects for significant decarbonisation in the UK and internationally over the coming century, and the improved representation in Integrated Assessment Models of carbon flows though the economy and environment.

Research Theme 3 *(Adapting to Climate Change)* is assessing how people and the environment can adapt to changes in climate, whether gradual and continuous or abrupt and extreme. Most discussions about climate change focus on gradual changes in average climate conditions. But climate change will also influence the occurrence of extreme weather events, such as floods, droughts, heat waves and windstorms. The climate system may also change rapidly – as has happened in the past. Research in this Theme will provide information to help put protective measures into action that minimise adverse impacts on society and avoid dangerous changes to climate.



The Tyndall Centre's four Research Themes (red) are integrated with research partners and stakeholders (yellow) within the wider research contexts of climate change research, sustainability and global change science.

Research Theme 4 *(Sustaining the Coastal Zone)* contributes to the understanding of natural processes and human activities around coastlines in the UK and other countries. The research will identify the right mix of coastline defence options; from redesigning the structure of coastlines to accommodate higher sea levels and storm surges, to engineering options such as reinforcing sea walls to conserve ecologically, culturally and socio-economically important areas. Radically new management strategies such as relocation must be supported by careful analysis and wide participation, so new methods of stakeholder involvement (such as virtual-reality sessions) will be required. The research demonstrates the focused use of Research Theme 1's integrated assessment and modelling, in a local, vulnerable environment.

Externally funded projects

Duration	Value	Project title	Funder	Most relevant research theme
04/00-03/02	£154k	UKCIP 2002 climate scenarios	DEFRA	RT1
06/01-09/01	£10k	Carbon lifestyles and future climates (Whitehall Summer Placement Scheme)	DLTR	RT2
01/02-03/02	£12k	Area-based carbon emission reduction scoping study	Sustainable Development Commission	RT2
01/02-03/02	£7k	Cluster mapping and action plan development: Renewable energy	North West Development Agency	RT2
06/00-05/02	£38k	Climate change, ozone depletion and human health	MRC/NERC	RT3
02/01-01/03	£28k	Advanced Terrestrial Ecosystem Analysis and Modelling (ATEAM)	European Commission	RT3
01/02-12/02	£80k	Technical support and training for scenario development in assistance of the Assessment of Impacts and Adaptation to Climate Change in Multi Regions and Sectors (AIACC) project	Third World Academy of Sciences/GEF/ United Nations Environment Programme	RT3
10/01-04/02	£10k	Artist's residency and commission, in response to issues related to climate change	Calouste Gulbenkian Foundation	External Communications
2001-2005	£98k	External funding for research studentships	Various	Various

Tyndall research projects

RESEARCH THEME 1: Integrating Frameworks

Technology and the economy-energy system in an integrated assessment of climate change. Lead investigator: Dr J Köhler, Cambridge University (j.kohler@ecom.cam.ac.uk)

Evaluation of approaches to integrated assessment: A blueprint approach. Lead investigator: Dr R Warren, UEA (r.warren@uea.ac.uk)

Developing discourse coalitions to incorporate stakeholder perceptions and responses within the Tyndall IA. Lead investigator: Dr S Shackley, UMIST (simon.shackley@umist.ac.uk)

Planning & prototyping a climate module for the Tyndall integrated assessment model. Lead investigator: Prof. J Shepherd, Southampton Oceanography Centre (j.g.shepherd@soc.soton.ac.uk)

Interfacing climate and impacts models in integrated assessment systems. Lead investigator: Prof. N Arnell, University of Southampton (N.W.Arnell@soton.ac.uk)

Etech+: Technology policy and technical change, a dynamic global and UK approach. Lead investigator: Prof. D Anderson, Imperial College (dennis.anderson@ic.ac.uk)

Uncertainties in the integrated assessment process. Lead investigator: Mr P Challenor, Southampton Oceanography Centre (P.Challenor@soc.soton.ac.uk)

The creation of a pilot phase Interactive Integrated Assessment Process for managing climate futures. Lead investigator: Dr A Haxeltine, UEA (alex.haxeltine@uea.ac.uk)

SOFTIAM: Integrated assessment modelling using distributed software components. Lead investigator: Dr R Warren, UEA (r.warren@uea.ac.uk)

RESEARCH THEME 2: Decarbonising Modern Societies

Evaluating policy options for the clean development mechanism: A stakeholder multi-criteria approach. Lead investigator: Dr K Brown, UEA (k.brown@uea.ac.uk)

Carbon sequestration: A pilot stage multi-criteria evaluation of biological and physio-chemical approaches. Lead investigator: Dr S Shackley, UMIST (simon.shackley@umist.ac.uk)

Sustainable building form: The role of architecture and urban planning with respect to climate change. Lead investigator: Dr K Steemers, Cambridge University (kas11@cam.ac.uk)

The hydrogen energy economy: its long term role in greenhouse gas reduction. Lead investigator: Dr J Halliday, RAL (J.A.Halliday@rl.ac.uk)

Fuel cells: Providing heat and power in the urban environment. Lead investigator: Dr J Halliday, RAL (J.A.Halliday@rl.ac.uk)

Integrating renewables and CHP into the UK electricity system. Lead investigator: Prof. N Jenkins, UMIST (n.jenkins@umist.ac.uk)

Microgrids: distributed on-site generation. Lead investigator: Dr T Markvart, Southampton University (t.markvart@soton.ac.uk)

Behavioural response and lifestyle change in moving to low carbon transport futures. Lead investigator: Dr A Bristow, ITS (Leeds) (abristow@its.leeds.ac.uk)

An integrated assessment of geological carbon sequestration in the UK. Lead investigator: Dr S Shackley, UMIST (simon.shackley@umist.ac.uk)

Critical issues in decarbonising transport. Lead investigator: Mr M Fergusson, IEEP (mfergusson@ieeplondon.org.uk)

The 40% house. Lead investigator: Dr B Boardman, ECI, University of Oxford (Brenda.Boardman@eci.ox.ac.uk)

Security of decarbonised electricity systems. Lead investigator: Prof G Strbac, UMIST (g.strbac@umist.ac.uk)

RESEARCH THEME 3: Adapting to Climate Change

Scenario development methods for the estimation of future probabilities of extreme weather events. Lead investigator: Prof. M Hulme, UEA (m.hulme@uea.ac.uk)

Accuracy of modelled extremes of temperature and climate change and its implications for the built environment in the UK. Lead investigator: Dr G Levermore, UMIST (geoff.levermore@umist.ac.uk)

Integrated assessment of the potential for change in storm activity over Europe: Implications for insurance and forestry. Lead investigator: Dr J Palutikof, UEA (j.palutikof@uea.ac.uk)

New indicators of vulnerability and adaptive capacity. Lead investigator: Dr N Adger, UEA (n.adger@uea.ac.uk)

Business and climate change: Measuring and enhancing adaptive capacity. Lead investigator: Prof. D Gann, SPRU (d.gann@sussex.ac.uk)

Adaptations to climate change amongst natural resource-dependant societies in the developing world: Across the southern African climate gradient. Lead investigator: Prof. D Thomas, University of Sheffield (d.s.thomas@shef.ac.uk)

Climate outlooks and agent-based simulation of adaptation in Africa. Lead investigator: Dr R Washington, University of Oxford (richard.washington@geog.ox.ac.uk)

Sustainable water resources: A framework for assessing adaptation options in the rural sector. Lead investigator: Dr K Weatherhead, Cranfield University (k.weatherhead@cranfield.ac.uk)

A strategic assessment of equity and justice implications of adaptation. Lead investigator: Mr J Lefevere, FIELD (Jurgen.lefevere@field.org.uk)

RESEARCH THEME 4: Sustaining the Coastal Zone

Towards a vulnerability assessment for the UK coastline. Lead investigator: Dr M Tsimplis, Southampton Ocenaography Centre (mnt@soc.soton.ac.uk)

Towards an integrated coastal simulator of the impact of sea level rise in East Anglia. Lead investigator: Prof. A Watkinson, UEA (a.watkinson@uea.ac.uk)

Linking sea level rise, coastal biodiversity and economic activity in Caribbean island states: A pilot study. Lead investigator: Prof. A Watkinson, UEA (a.watkinson@uea.ac.uk)

Integrated modelling of an estuarine environment: An assessment of managed realignment in estuaries. Lead investigator: Prof. T Jickells, UEA (t.jickells@uea.ac.uk)

Responding to climate change: Inclusive and integrated coastal analysis. Lead investigator: Dr K Brown, UEA (k.brown@uea.ac.uk)

Visualising coastal futures: Technologies for decision making in participatory coastal management. Lead investigator: Dr A Jones, UEA (a.p.jones@uea.ac.uk)

Interactions between tourism, biodiversity and climate change in the coastal zone. Lead investigator: Prof. W Sutherland, UEA (w.sutherland@uea.ac.uk)

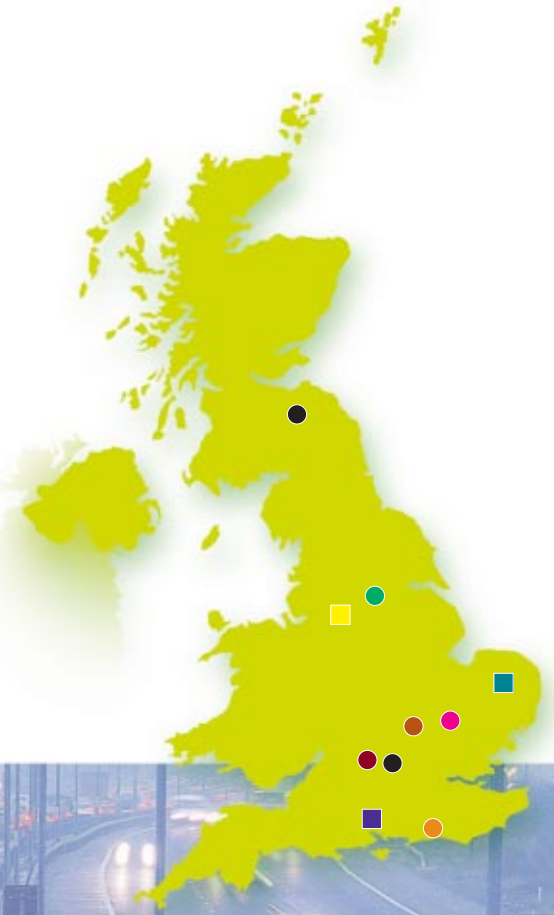
An integrated coastal-sediment dynamics and shoreline response simulator. Lead investigator: Dr J Rees, BGS (jgre@bgs.ac.uk)

Regional assessment of coastal flood risk. Lead investigator: Prof. R Nicholls, Middlesex University (r.nicholls@mdx.ac.uk)

Tyndall Centre Publications

A full list of the Tyndall Centre's reports and publications is available at www.tyndall.ac.uk/publications/publications.shtml

Tyndall Centre
for Climate Change Research



Tyndall Partners

- University of East Anglia
- UMIST
- University of Southampton and Southampton Oceanography Centre
- University of Cambridge
- SPRU (Science and Technology Policy Research), University of Sussex
- ITS (Institute for Transport Studies), University of Leeds
- NERC Centre for Ecology and Hydrology Bush & Wallingford
- Cranfield University
- Energy Research Unit (CLRC-RAL)

A range of further information, including contact details for project leaders and other staff, fact sheets about the Tyndall Centre's research, the Tyndall Centre's Research Strategy, and a quarterly electronic newsletter, is available from our website: **www.tyndall.ac.uk**

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NATURAL ENVIRONMENT RESEARCH COUNCIL

EPSRC
Engineering and Physical Sciences Research Council

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

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