Institute for Energy Systems

PROF MARKUS MUELLER
SCHOOL OF ENGINEERING
THE UNIVERSITY OF EDINBURGH

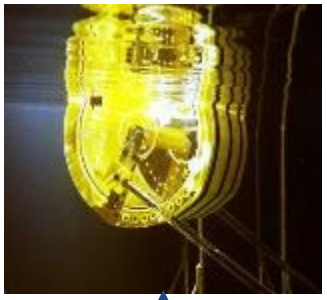
Institute for Energy Systems

- Aims to conduct research into:
  - Low and zero carbon production of energy
  - The distribution of energy from low and zero carbon sources
  - The incorporation of new knowledge into public and industrial policies at a national and international scale

Institute for Energy Systems

- 26 academic staff, 23 research staff and over 73 postgraduate students.
- Research funding of £20m from
  - UK Research Councils
  - European Commission
  - Energy Technologies Institute
  - Carbon Trust
  - Scottish Enterprise
  - Industry
  - Government, UK and Scottish

The Renewables Challenge

Resources	Capture	Conversion	Delivery
			
Energy and Climate	Marine & Wind Energy	Machines Power Electronics & Control	Power Systems Smart Grids Energy Storage

Innovation Policy and Regulation Standards Environment

IES research spans and maps to the renewable energy supply chain

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Offshore Renewables

David Ingram
Venki Venugopal
Ignazio Maria Viola
Alistair Borthwick
Robin Wallace
Tom Bruce
Ton van der Bremer
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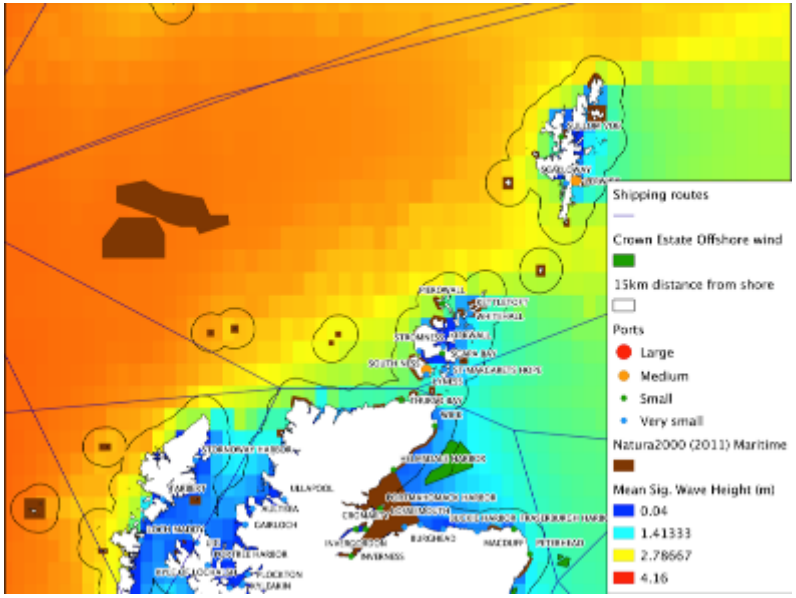
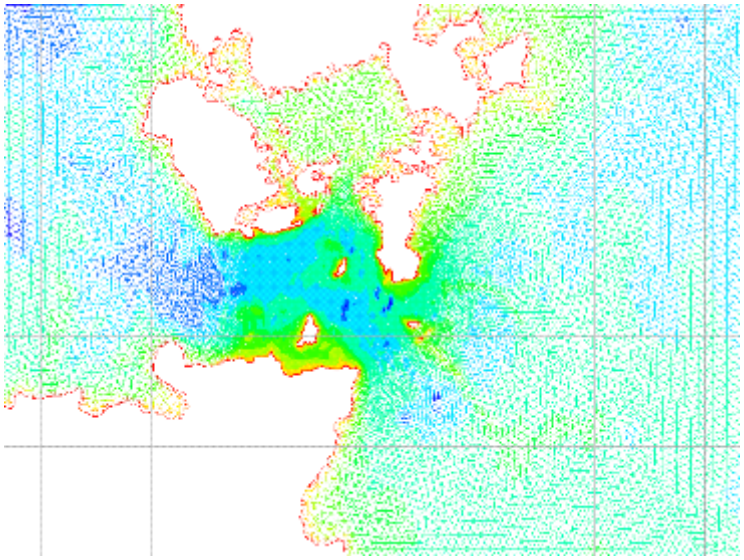
Resource Analysis





Geographical Information Systems (GIS)

GIS tool incorporating ten years of hind cast wind, wave and tidal data for all European Waters.

Shallow Water Modelling

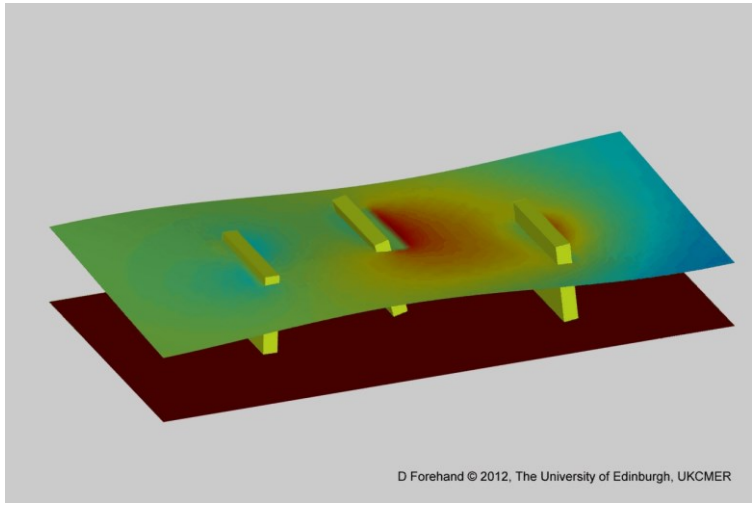
Flow through the Pentlad Firth, including the MeyGen tidal turbine array in the Inner Sound.

David Forehand – Some Wave Energy Research in IES

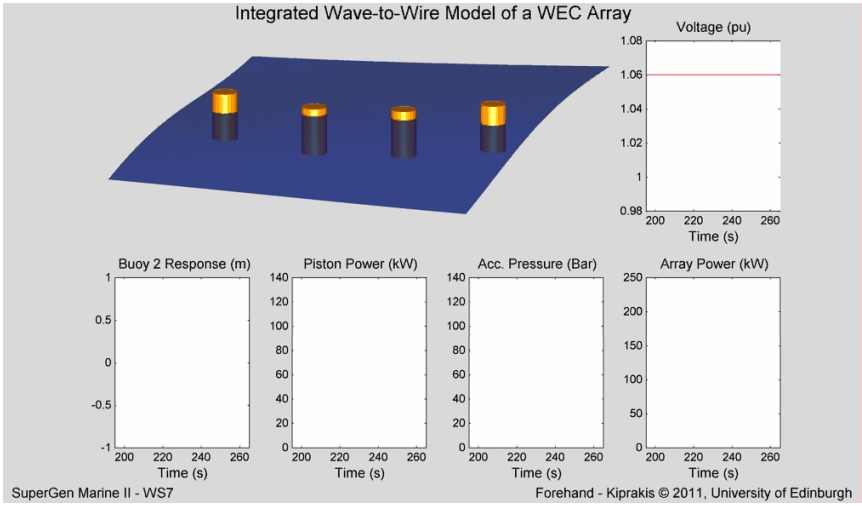
Time-Domain Hydrodynamic Modelling of WEC Arrays

- As the wave energy sector moves from single device installations to the deployment of multiple machines, *accurate array models* will be necessary.
- Traditional *frequency-domain* codes are limited – they can't model *transient behaviour* or incorporate *additional nonlinear forces*.
- We need to move to the *time-domain*.
- We have developed a time-domain, hydrodynamic WEC *array* model.
- It takes into account *all* the hydrodynamic interactions between *all* the converters.
- It models *any number*, *shape* and *configuration* of devices in an array, each moving in up to 6 degrees of freedom. It is *fast* but captures most of the essential physics.

Interacting Array of Oscillating Flaps



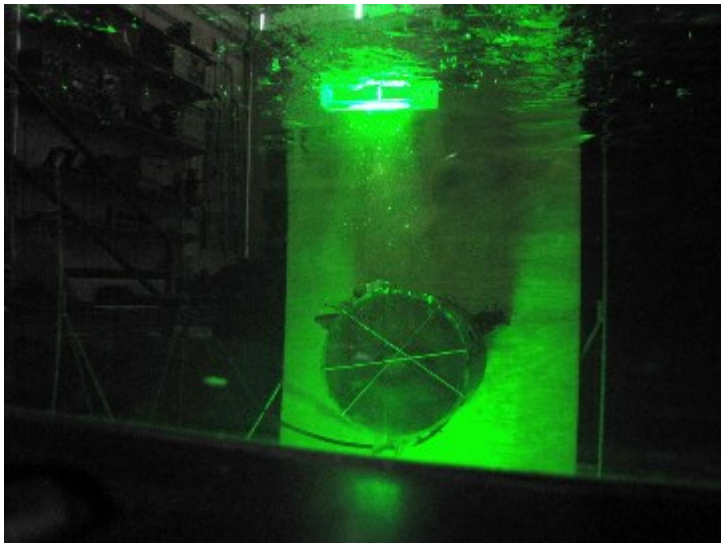
Wave-to-Wire Model of Heaving Buoy Array



Marine Energy Testing

Hydrodynamic testing of marine energy devices.

Curved wave basin



Laboratory Measurement

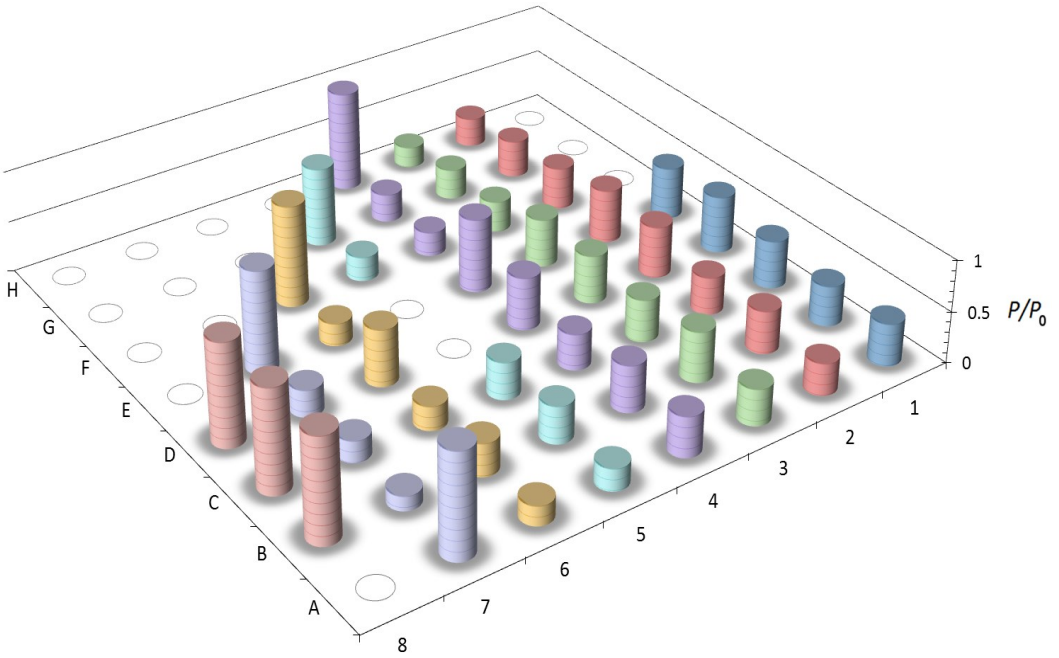
e.g. PIV Measurement of impeller wake.

New MarineTest Facility

Field Measurements

Acoustic Doppler velocity measurements on a tidal turbine deployed at the EMEC test site,

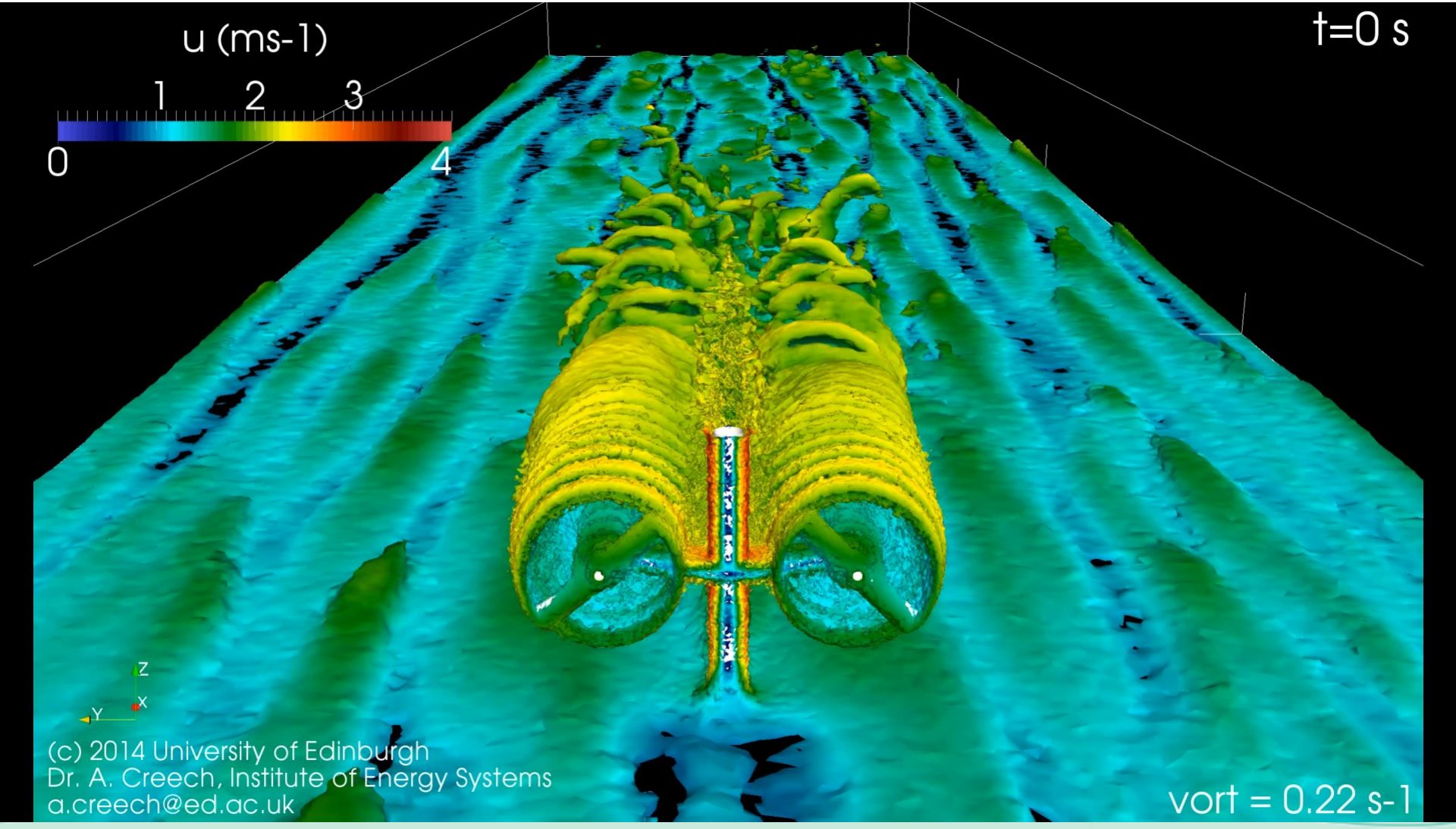
Computational Fluid Dynamics



BEMT Actuator line model of the Lillgrund Offshore Wind Farm

Marine Current Turbine

Computational Fluid Dynamics



Idcore

Industrial Doctoral Centre for Offshore Renewable Energy

The University of Edinburgh

University of Exeter

University of Strathclyde Glasgow

HR Wallingford
Working with water

Scottish Association for Marine Science

Energy

energy technologies institute

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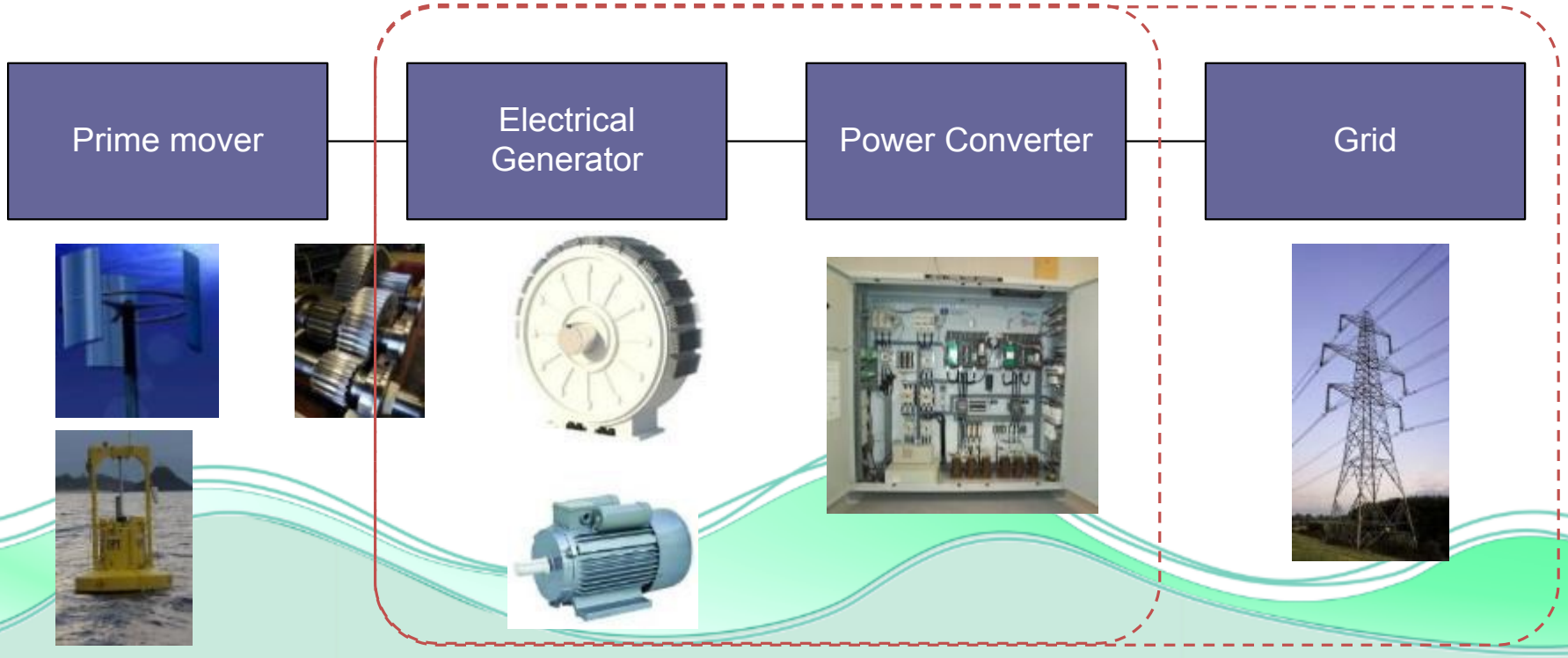
Advanced Control and Electrical Power Conversion

Jonathan Shek
Ewen Macpherson
Quan Li
Markus Mueller

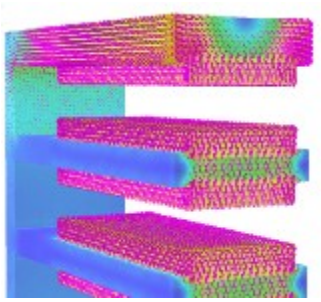
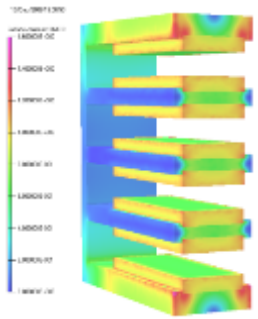
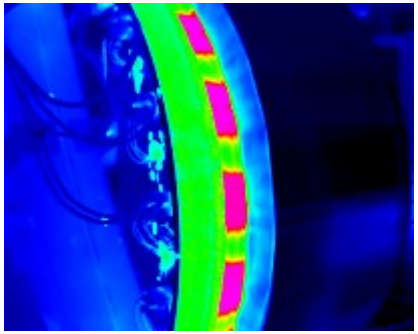
Institute for Energy Systems

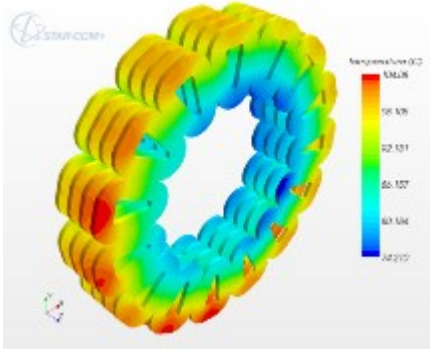
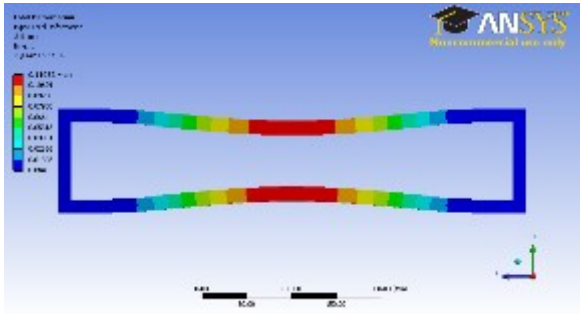
Research Interests

- Power conversion and control for renewable energy



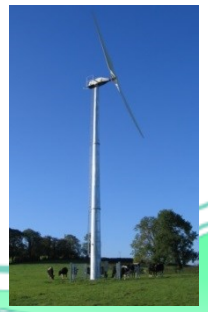
Electrical Machines

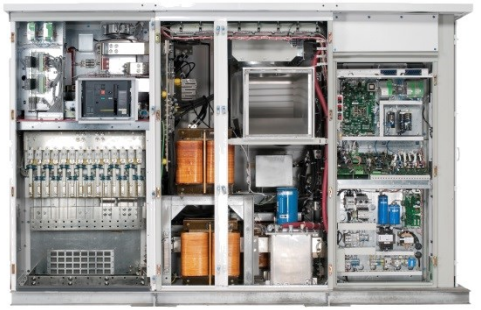

Hybrid power systems

- Wind-Diesel-Battery systems
  - Innovate and improved solutions for the management of power flows in a hybrid electrical power system
  - Higher efficiency and improved techno-economic performance.
  - Increase generation capacity in weak grids using energy storage



Electrical modelling

- Tidal current turbines
  - Compare different generator technologies and control theories
  - Validate models using real measured data
  - Perform harmonic analysis and accurate loss modelling based on temperature/frequency variations
  - Suggest cost-effective solutions for device developers



All Electric Drive Marine Energy Converters

- EPSRC Marine Grand Challenge Project
  - 1st April 2016 – 31st March 2019
- UK Partners
  - Edinburgh, Newcastle
- International Partners
  - Universidad de Chile, Prof Roberto Cardenas
  - TU Delft, Dr. Henk Polinder

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Power Systems

Sasa Djokic
Aristides Kiprakis
Harry Van de Weijde
Gareth Harrison

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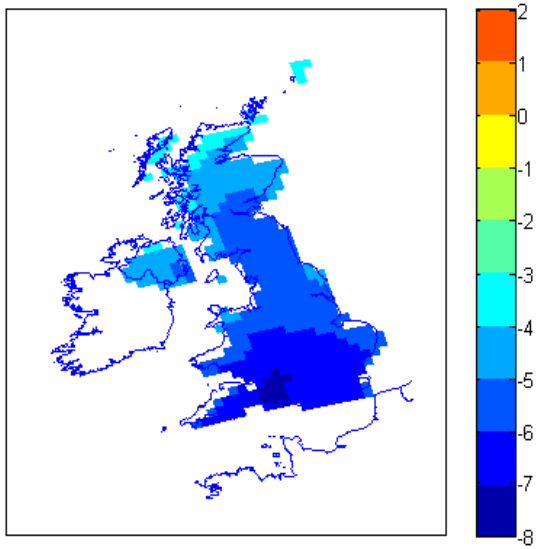
Climate Change and Energy Systems

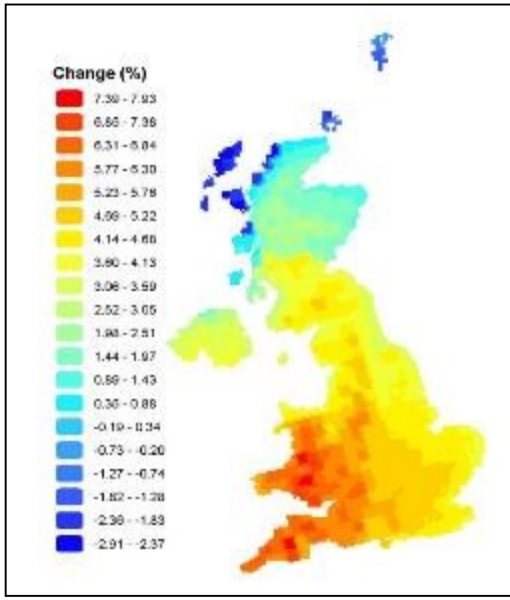
Electricity Networks

Increasing temperature could reduce network capacity in future

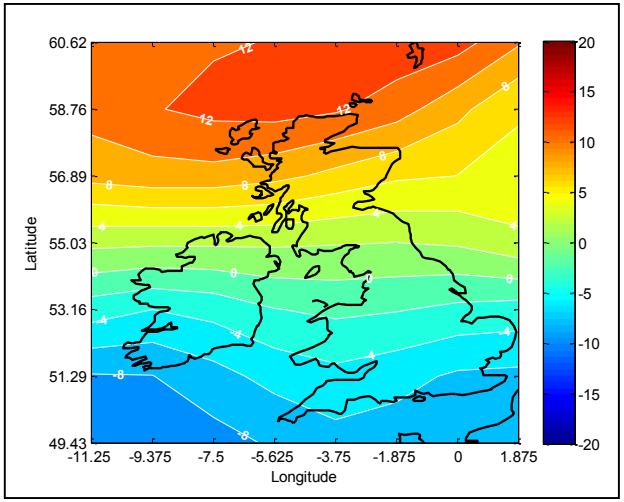


Solar Energy

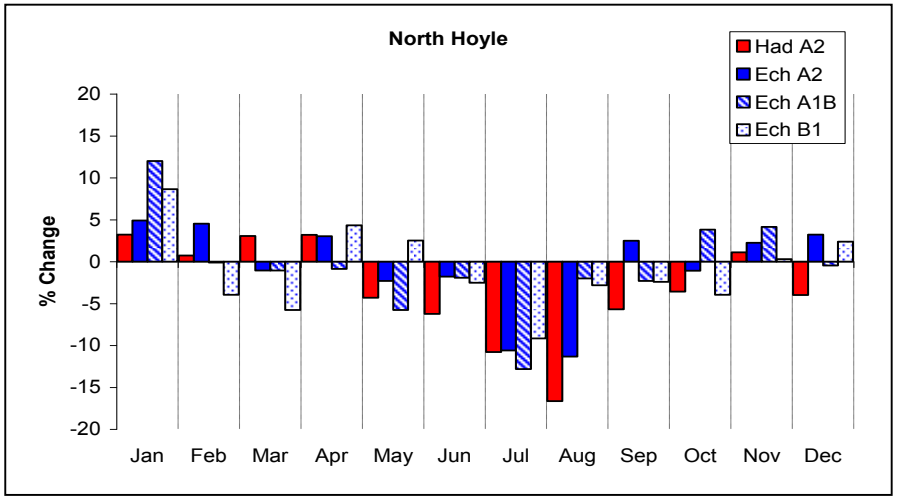
Patterns of solar energy may change throughout the country



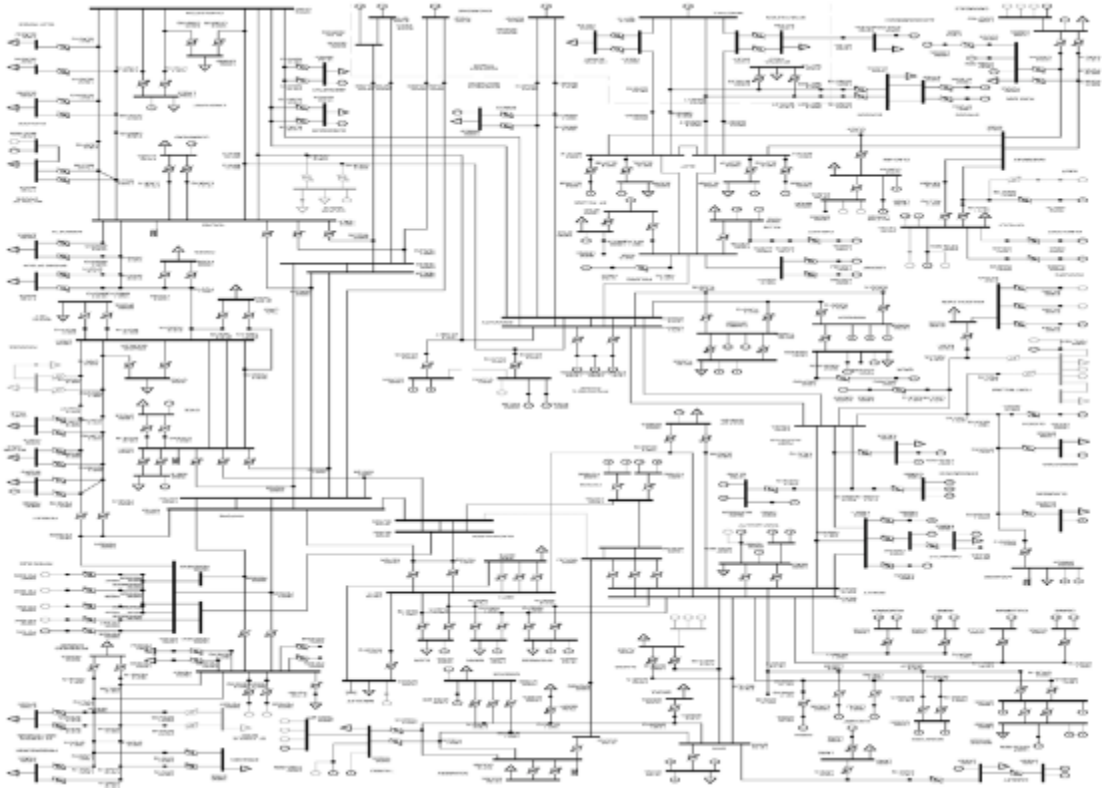
Wind Energy



Wind production could become more seasonal – lower in summer, higher in winter



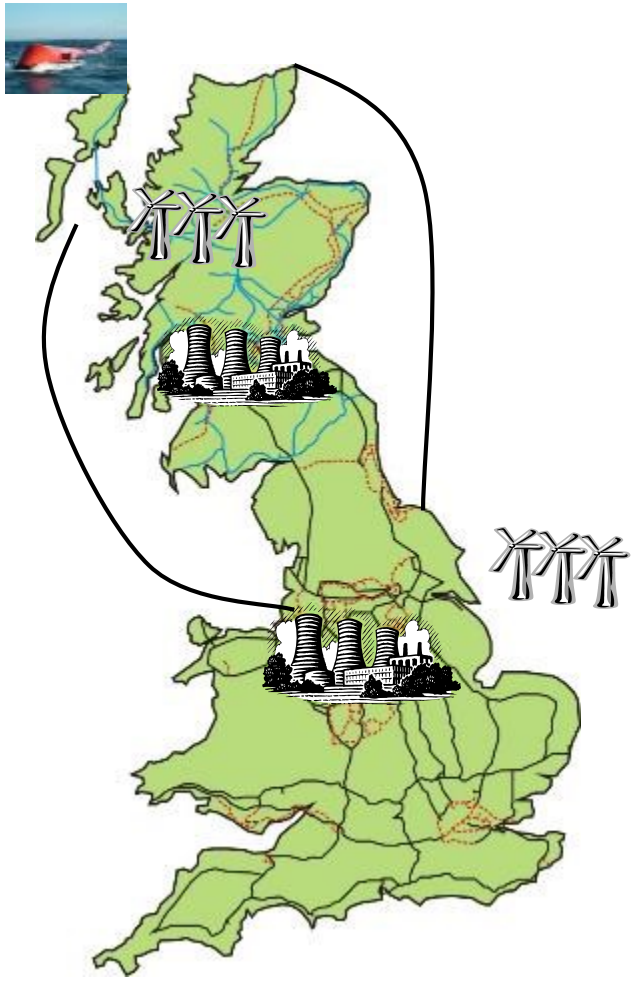
Electrical Power Networks



Independently developed model of the Scottish Transmission and Distribution Grids.

Power Networks & SMART Grids

- Research focussed on the implications of rapidly changing energy supply
  - renewables with very different spatial and temporal characteristics
  - offshore grids, electric vehicles, storage and ‘active’ demand
- Broad range of activity
  - Integration of distributed renewables
  - AC-DC integration
  - Asset management
  - Power quality and reliability
  - Demand side management and modelling



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Energy Storage

Win Rampen
Daniel Friedrich
Dimitri Mignard
Jonathan Shek
Adam Robinson

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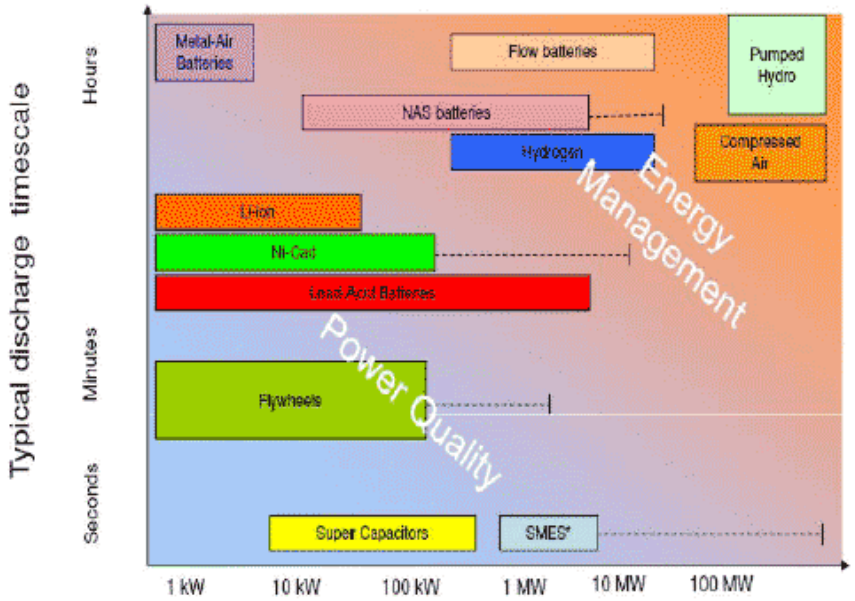
Energy storage technologies



www.scotland.gov.uk

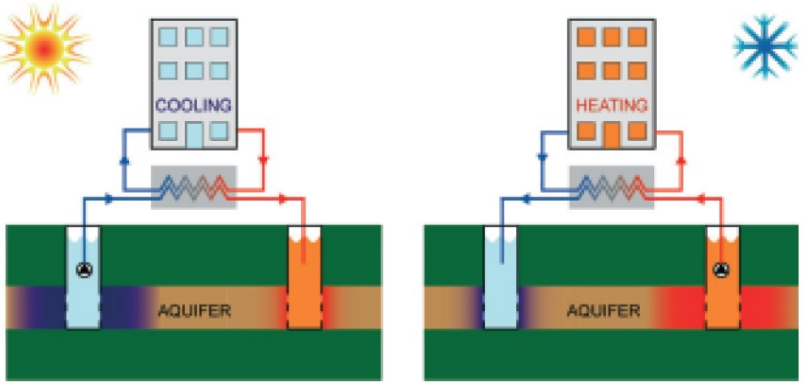
	UK	Scotland
Heat	41%	55%
Transport	33%	24%
Electricity	26%	21%

Not just electricity!

- About half of the demand is in heat
- A quarter in transport

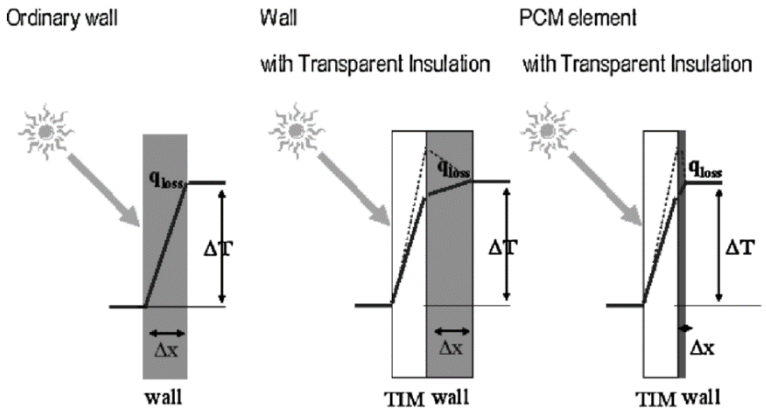
Thermal storage

- Cooling and heating
- Phase Change Materials incorporated into buildings
- Combination of storage and generation
  - Solar thermal collector
  - Heat pump

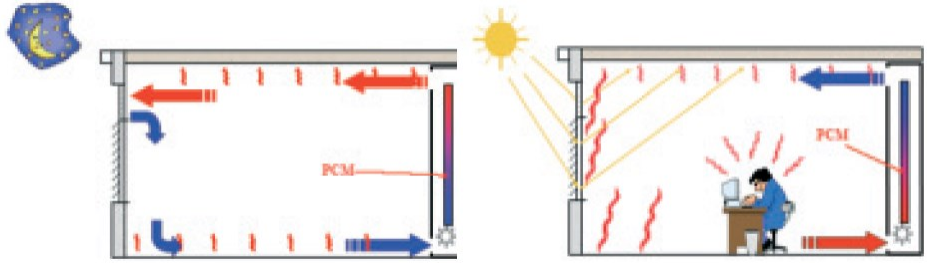


Summer: Cooling of office buildings / industrial processes

Winter: Heating of office buildings / industrial processes



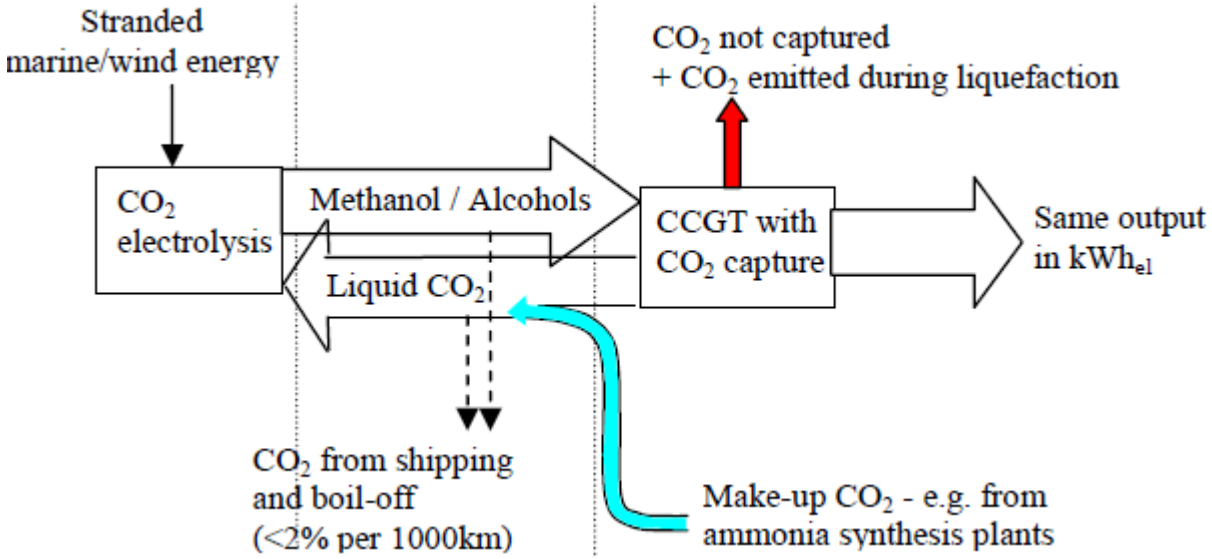
Mehling et al. APPLICATION OF PCM FOR HEATING AND COOLING IN BUILDINGS



International Renewable Energy Agency

Power-to-fuel

Dimitri Mignard and Colin L. Pritchard



- Hydrogen from electrolysis
- Fuel synthesis from hydrogen and CO_2
- EPSRC's SuperGEN Marine Energy Programme

Energy Storage for Marine

- Wave energy converter arrays
  - Use of energy storage for active control
    - Maximise power capture
    - Survivability
    - Network faults
  - On-grid and off-grid connection

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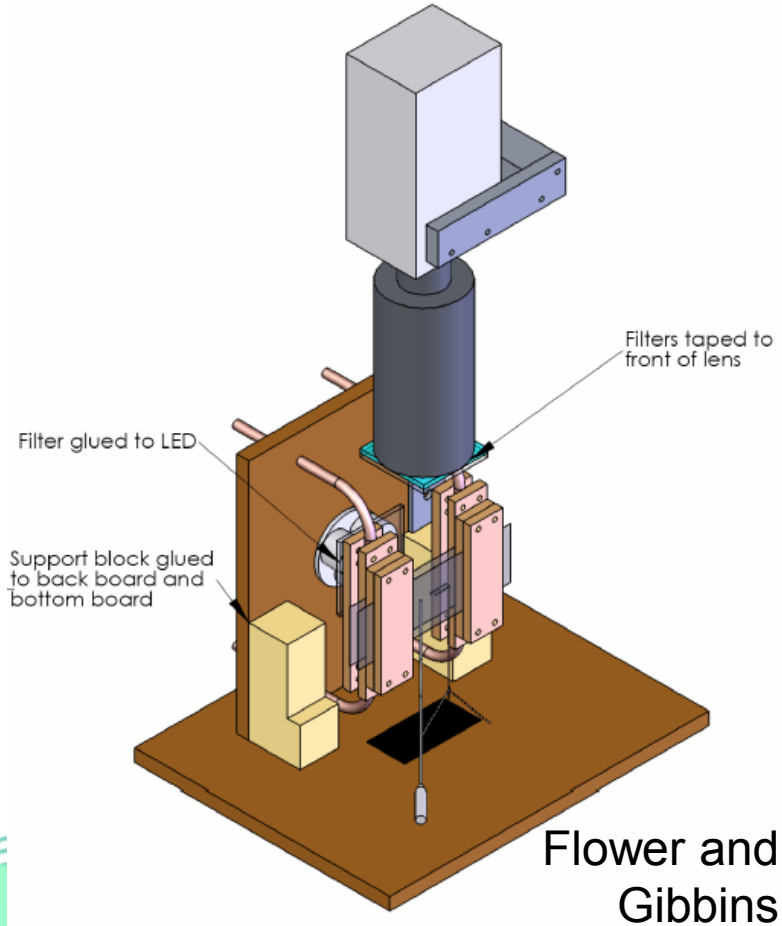
Combustion

Mark Linne
Brian Peterson
Donghyuk Shin
Hannah Chalmers
Mathieu Lucquiaud

Institute for Energy Systems

Fundamental combustion studies

- Unique facilities for studying single particle combustion of biomass and coal
- Contributing to UKCCSRC bio-CCS project and EPSRC conventional power consortium



Flower and Gibbins (2009)

CLEAN COMBUSTION: IC ENGINE

- Advanced laser diagnostic techniques and new approaches to computational modelling, used across the entire international research community, have allowed us to understand much better what is going on inside an IC engine combustion chamber

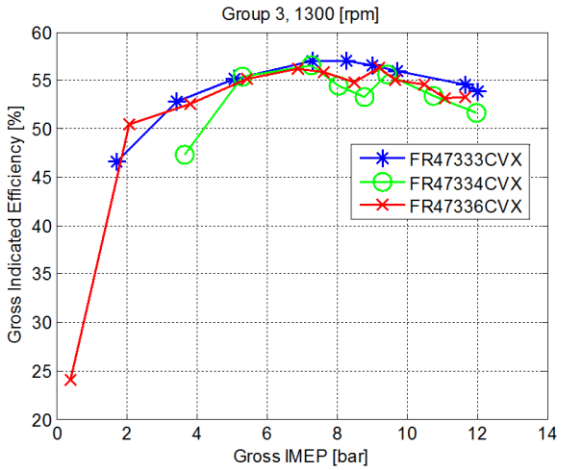
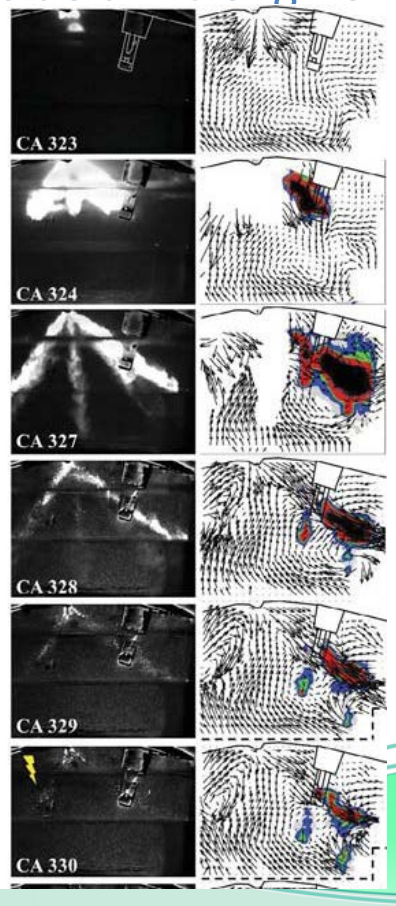


Image courtesy of Bengt Johansson at the University of Lund, Lund, Sweden



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Policy

Henry Jeffrey
Harry van der Weijde
Gareth Harrison
Hannah Chalmers

Institute for Energy Systems

Innovation and Policy

- Research focused on the dynamics of innovation in energy systems
  - relationships between policy, investment and innovation
  - Work closely with UK Energy Research Centre
- Broad range of activity
  - Techno-economic analysis
  - Roadmaps and standards
  - Governance and policy
  - Innovation systems
  - Societal engagement with energy

UKERC

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MARINE ENERGY DEVELOPMENT

TAKING STEPS FOR DEVELOPING THE CHILEAN RESOURCE

E&A ERRAZURIZ & ASOCIADOS

British Embassy Santiago

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QUESTIONS