CESI

National Centre for
Energy Systems
Integration

EPSRC National Centre for Energy System Integration (CESI)

Introduction

- A unique £20m EPSRC National Centre for Energy Systems Integration (CESI)

- Wide spectrum of industrial and academic energy experts from around the world

- Collaborative five year research program

- Core funded by Siemens AG, with an additional £5m from EPSRC, and the balance from industry and academic partners

- The Centre aims to investigate the challenges of the energy trilemma of security of supply, sustainability and affordability.

- Looking at the energy system as a whole incorporating heat, transport and electricity

- Paves the way to a flexible smart infrastructure, empowering customers and giving them greater control of their energy use while allowing industry to meet the tough new low carbon targets.
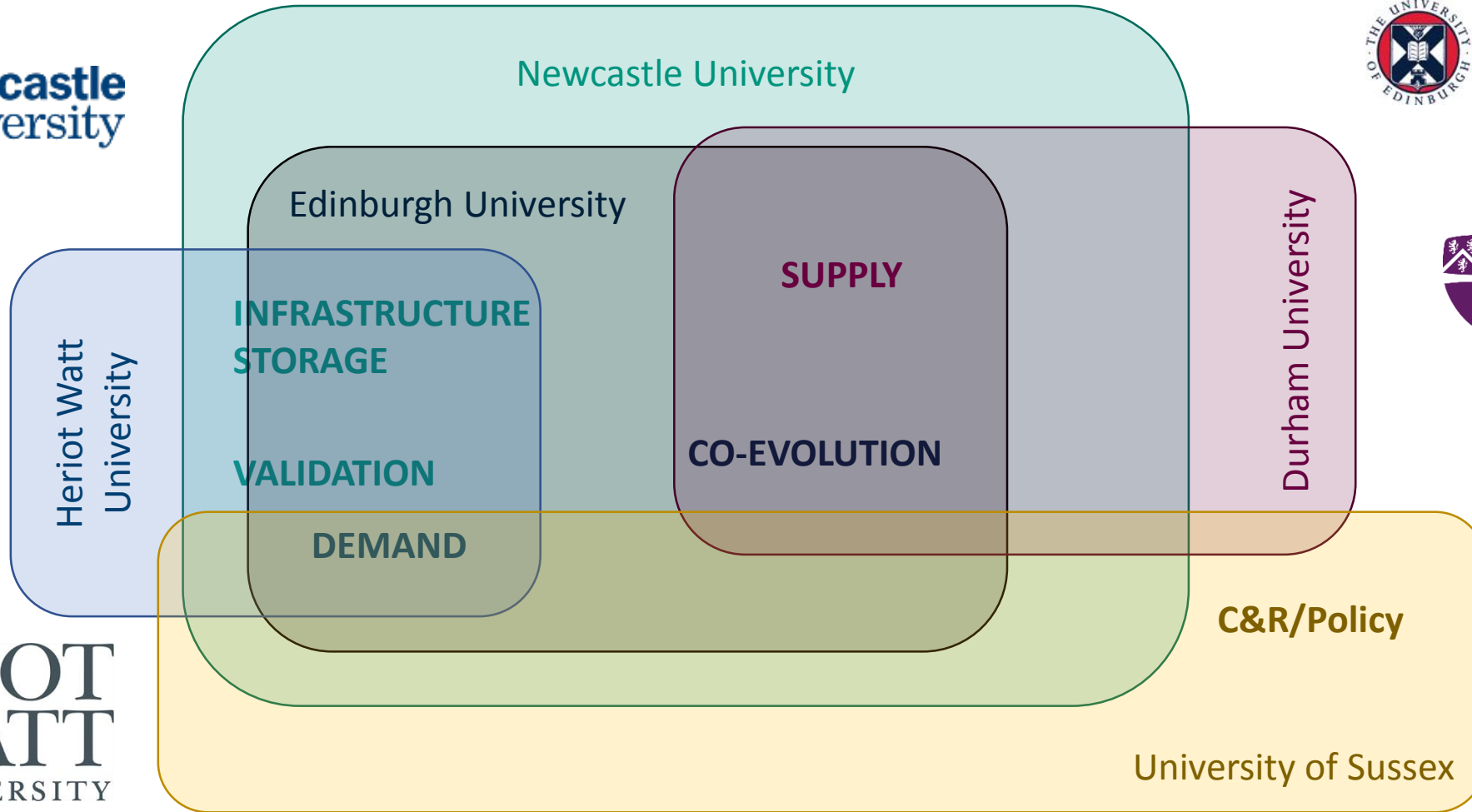
Research Programme

Seven Work packages

- WP1 Commercial, regulatory and policy aspects

- WP 2 Energy supply

- WP3 Infrastructure and storage

- WP4 Energy demand

- WP5 Validation and demonstration

- WP6 Architecture

- WP 7 Impact, engagement and management

Highly collaborative and Multi Disciplinary

Introduction to the CESI Work packages

Work Package 1
Professor Gordon MacKerron, SPRU, Sussex
Commercial, Regulatory and Policy aspects

Work package overview, aims and objectives

Overarching aim: integrate insights from social science and policy analysis through all work packages

Objectives

- Inform the development of modelling in other WPs

- Examine social and economic implications of model outputs, including for regulatory structures

- Identify priority areas for innovation and investment

- Monitor demand side issues, especially work of EUEDs

- Apply sociology of science to modelling , assessing modelling shortcomings

- Prepare for each co-evolution cycle

Methods, tools and datasets

- Regulatory, energy and environmental economics

- Sociology of science

- Innovation theory, including sustainability transitions

- Data sets from EUED centres, UKERC, ETI, possibly Systems Catapult and others to be explored from other CESI WPs

Deliverables

- The use of language across disciplines (Q2)

- Review of current energy policy directions/Fifth Carbon budget and Brexit implications (Q2)

- Alternatives to large-scale nuclear investment (Sizewell C and beyond) (Q3)

- Other deliverables on:
  - scenario inputs
  - innovative business models
  - regulatory implications of low carbon electricity system and the increasing penetration of electricity into transport and heat, including infrastructure investment implications
  - others to be negotiated, and advised......

Interface

- Interfaces with all WPs on an ongoing basis, with two-way feedback

- Particularly strong interface with WP4 (demand issues, including monitoring of EUED centres) WP6 especially on sociology of science issues, and WP7 on engagement

- Important interface externally with UKERC in relevant areas

- Expectation of face to face meetings at regular intervals with WP leaers in these areas

Resource Plan

- WP1 has 3.5 years of RA to recruit. This recruitment has been postponed pending clarifying relationships with other WPs, and division/connection between Sussex and Durham resources

- Engagement with BEIS, the Committee on Climate Change, and EUEDs are strong priorities, plus other UK energy research centres

- UKERC especially important – they have programmes on future energy system pathways, resources/vectors, energy at multiple scales, energy, economic and societal preferences, decision making and technology and policy assessment

WP2: Energy Supply
Prof. Simon Hogg

DONG Professor in Renewable Energy
Executive Director Durham Energy Institute
School of Engineering
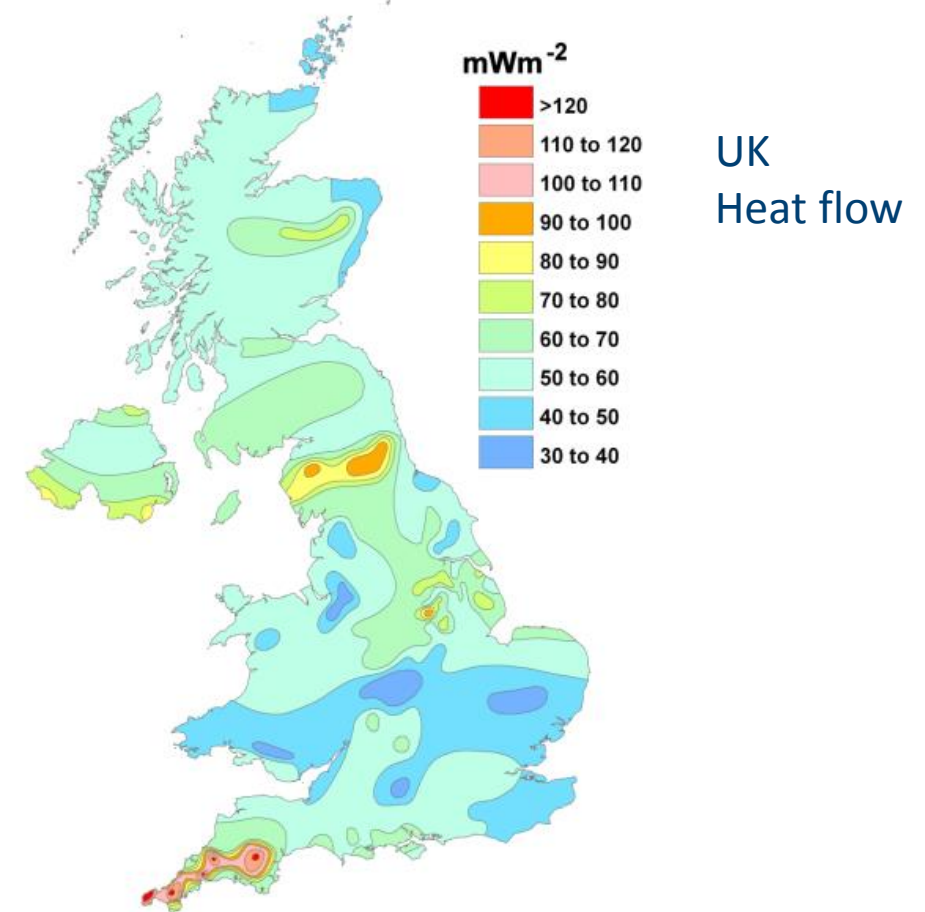Durham University, DH1 3LE, UK.

Telephone: +44 191 334 1513
Mobile: +44 7584 174707
Email: simon.hogg@durham.ac.uk

WP2 overview, aims and objectives

To:

- Investigate and map current and future UK sources of energy supply.
  - Heat & power

- Analysis of how supply-side technologies may evolve:
  - resource availability
  - reliability
  - system design
  - techno/socio/economic aspects of deployment.

- Evaluation of uncertainties associated with key large-scale low-carbon technologies

UK
Heat flow

mWm^{-2}
- >120
- 110 to 120
- 100 to 110
- 90 to 100
- 80 to 90
- 70 to 80
- 60 to 70
- 50 to 60
- 40 to 50
- 30 to 40

WP2: Methods, tools and datasets

WP2 will use and develop:

- High resolution renewable resource datasets (wind, solar, hydro etc) - Edinburgh University

- Resource mapping & quantification - Durham University

- State of the art meteorological, oceanographic and hydrological models.

- High resolution demand and resource data for both electricity and heat supplied by project partners

- Statistical modelling techniques and expertise - Durham and Edinburgh Universities

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Eastgate 2, Geothermal research well, Durham

EPSRC
Engineering and Physical Sciences Research Council

WP2: Deliverables

- Resource maps and a techno/socio/economic assessment of unused low temperature heat sources, to examine their potential for reducing the use of gas and electricity in low grade heat production.

- Improved modelling of complex spatio-temporal characteristics of current and future renewable generation and demand to ensure that coherent time series data for supply, demand and infrastructure is available to inform system models.

- Synthesis models which compress the full multivariate time series while capturing the uncertainty in demand and renewable generation (needed by WP6).

- New statistical modelling techniques for estimating joint stochastic processes of variable generation resources and demand for both electricity and heat.

2MW turbine, Tow Law, Durham

WP2: Interfaces

In order to carry out the research in this workpackage, interfaces will be needed with:

- **WP3: Infrastructure and Storage**, particularly concerning the development of energy storage which will have a major impact on the future growth of renewable energy technologies.

- **WP4: Energy Demand**, in order to inform the work in WP2 of future needs for supply.

- The models and time series data sets output by WP2 will be used by **WP6 Multi-Scale Architectures, Planning and Operation**, to support the development of the whole system modelling tool.

- **WP5: Validation and Demonstration** to help to validated the models and data developed in WP2.

- Preparation for co-evolution cycles

WP2: Resource Plan

- Durham 3.5yr PDRA, Newcastle 1yr PDRA, Edinburgh 0.5yr PDRA, plus Durham 3.5yr PhD.

- Statistical modelling will be done jointly by Durham and Edinburgh – need to review PDRA resources following Dr Dent's move to Edinburgh.

- Immediate plan will be to recruit PDRA to start at Durham 3 to 6 months after project launch and PhD student to start 1 year after launch.

- Newcastle (1 yr) and Edinburgh (0.5 yr) will probably dedicate part of a PDRA's time to WP2 rather than recruiting a PDRA's to work solely on the workpackage as Durham will do.

- Engagement plans – BEIS, DONG & other external bodies

Offshore wind farm, Liverpool Bay
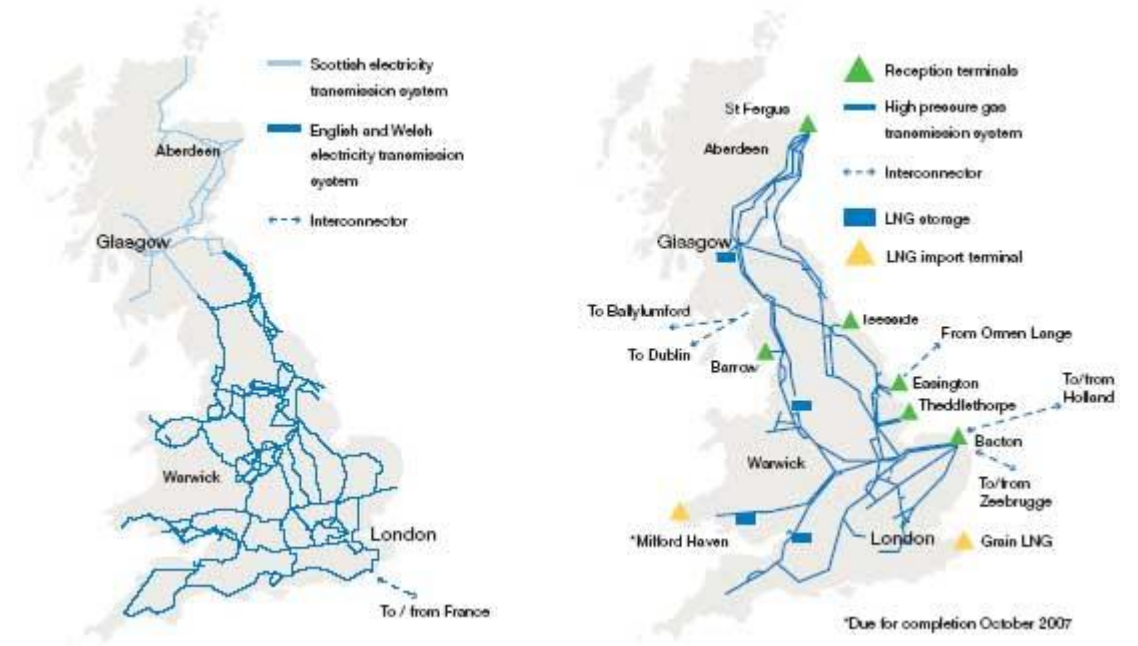
Work package overview, aims and objectives

- Workpackage is led by Prof. Tony Roskilly

- Total of 60 researcher months

- Collaboration between Swan Centre, University of Edinburgh and Herriot Watt

"Aim is to develop a method (numerical analysis tools with integrated and expert knowledge) which can be used to evaluate potential scenarios for energy infrastructure and storage out to 2050"

Methods, tools and datasets

Develop spatially detailed infrastructure models of

- *established energy vectors* (electricity, thermal, natural gas, petroleum)
- *growing energy vectors* (compressed air, hydrogen, bio-fuel, ammonia, *etc.*)
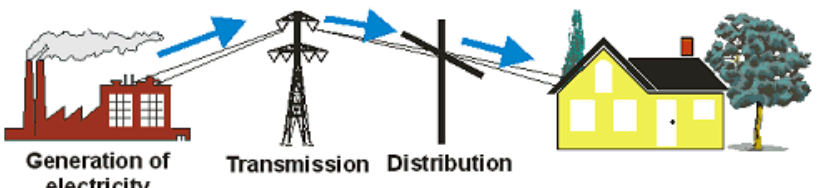- *symbiotic energy vectors* (combined heat and power, industrial waste-heat utilisation *etc.*).

These methods will be designed to accommodate the anticipated scale-up of energy storage capability, for

- *direct electricity storage* (batteries, super capacitors *etc.*)
- *in-direct electricity storage* (hydrogen, compressed air)
- *chemical storage* (natural gas, petroleum, ammonia)
- *thermal energy storage* (thermal storage and phase-change materials, boreholes/mines).

Integrate these models with multi-disciplinary working methods to enable us to support the co-evolution cycles
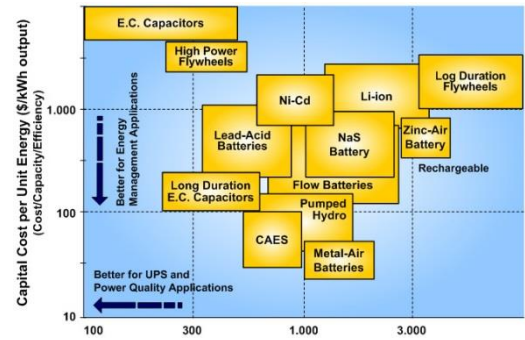
- Balance supply and demand temporally (*e.g.* half hourly, seasonally)
- Enable deterministic and probabilistic evaluation of cost, sustainability, interdependence and resilience
- Consider changing demographics, increased energy use, changes in the point of use, decentralisation of supply, migration to low-carbon technologies (including renewable generation), reducing/increasing demands on established infrastructure, and the changes to weather due to climate change evaluated in other work packages.

Deliverables

Develop an understanding of how the requirements for energy infrastructure (including energy storage) are likely to evolve in the years to 2050.

Landscape review of international research into energy storage, relevant energy vectors…..
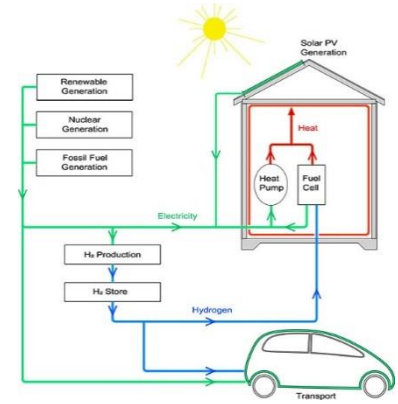
Establish tools and methods for working to support the integration of storage, infrastructure, supply and demand.

Identify synergies and interactions between energy storage, flexible demand and supply with other infrastructures.

Interface

The staged co-evolution cycles will ensure multi-disciplinary collaboration together with routine integration of models, data and expert knowledge.

- WP3 will bind together supply (WP2) and demand (WP4) work packages.

- The validation and demonstration (WP5) workpackage will provide supporting technical data.

- The multi-scale Architectures, Planning and Operation (WP6) workpackage will integrate with infrastructure and storage models into multi-stage planning tools.
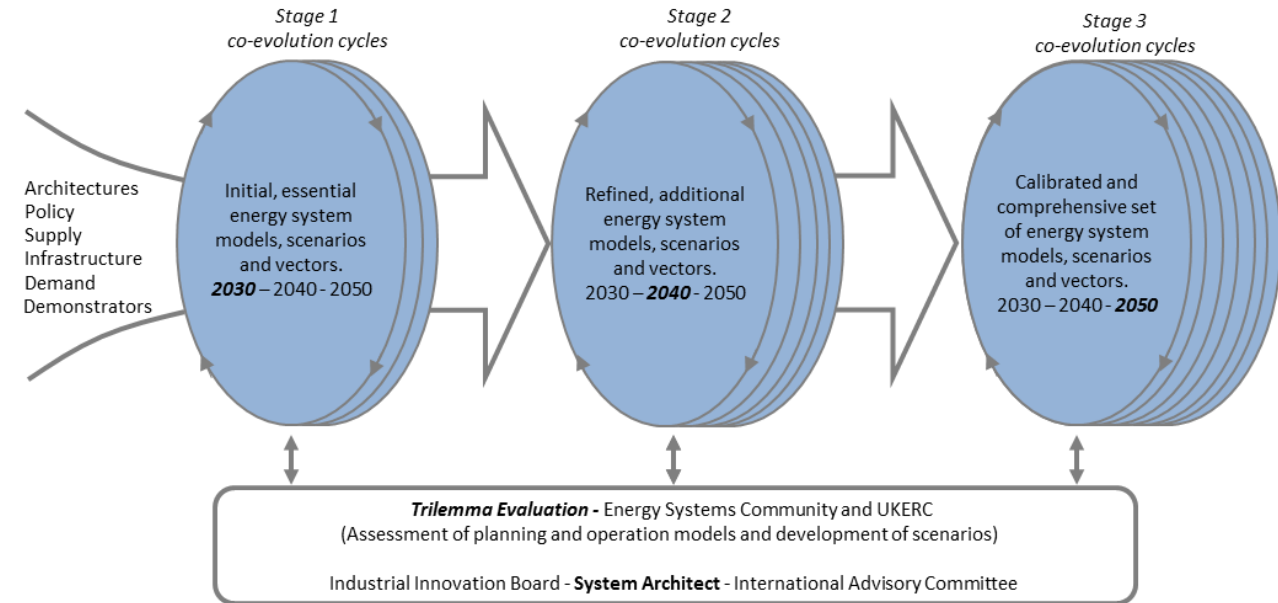
Resource Plan

Workpackage 3 has 60 months of FTE researcher time

- Newcastle University: 24 months (FTE) will be Dr Andrew Smallbone, Dr Mohammad Royapoor.

- University of Edinburgh: 24 months (FTE) will be recruited (electrical/gas).

- Herriot Watt University: 12 months (FTE) will be recruited (demand side experience).

Engagement plans...BEIS, UK energy research groups, network providers and their governance, technology providers.....

Dr David Flynn
WP4 Energy Demand

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Energy Demand Landscape
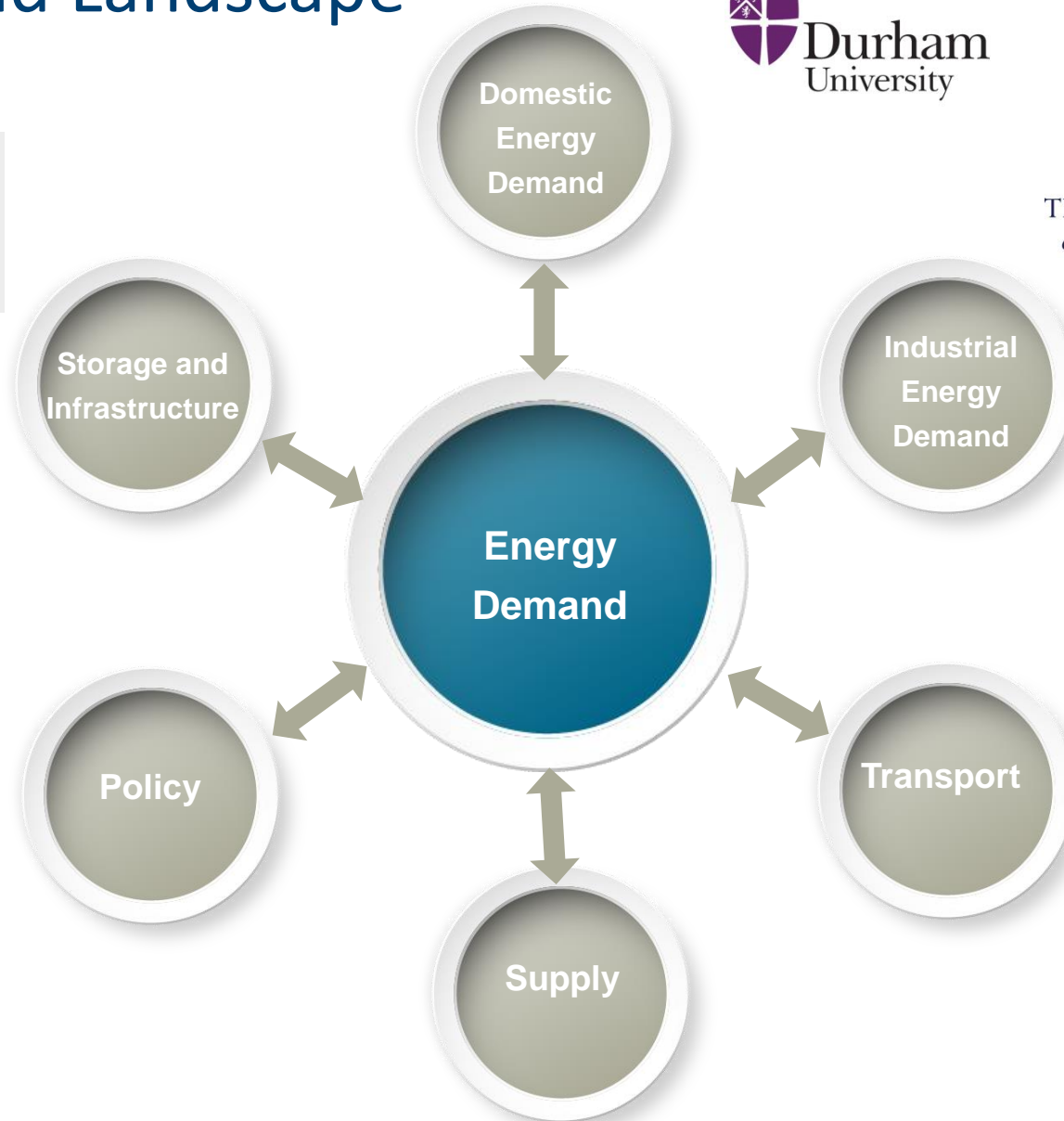
Work package overview

- Monitoring and Predicting the Impact of Energy Demand.
- Academic Partners: Newcastle, Sussex, Durham and Edinburgh
- Key Objectives:
  - Develop accurate modelling methods between the built environment and energy system modelling.
  - Provide analysis of system level relationships between electric, gas and heat within energy demand.
  - Create and Demonstrate Front End Embedded Intelligence for Optimisation of SCR.
  - Design and Optimisation of Community Coalitions (DSM).
  - Analysis of the impact of transport trends on energy demand.

Data Analysis

Case study and data analysis on an existing data set

- Feature selection and extraction
- ML algorithm

Prognostic model to estimate the RUL, Demand or Performance of the Asset

- Data collection
- Model refine

Prognostic module for energy system asset
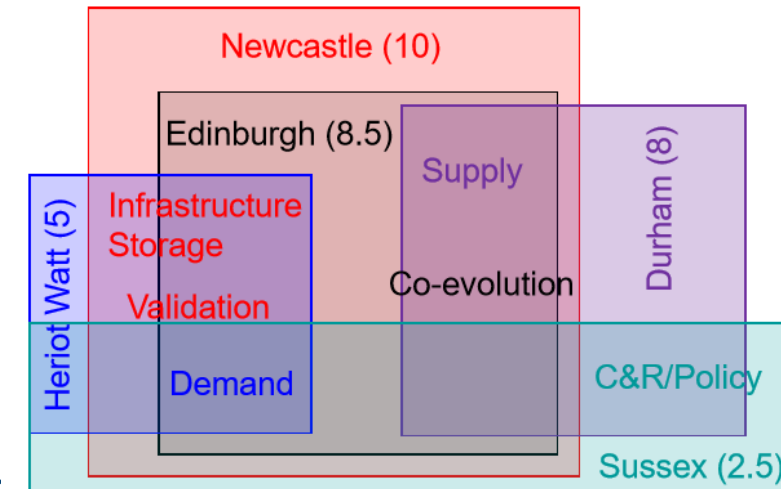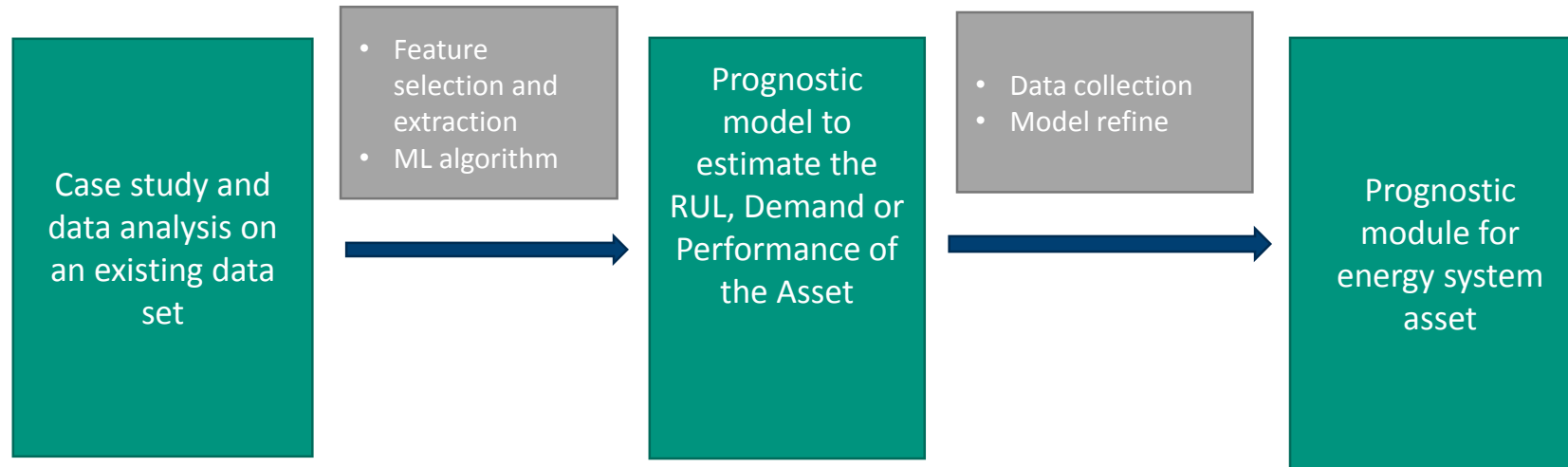
Fusion Analysis
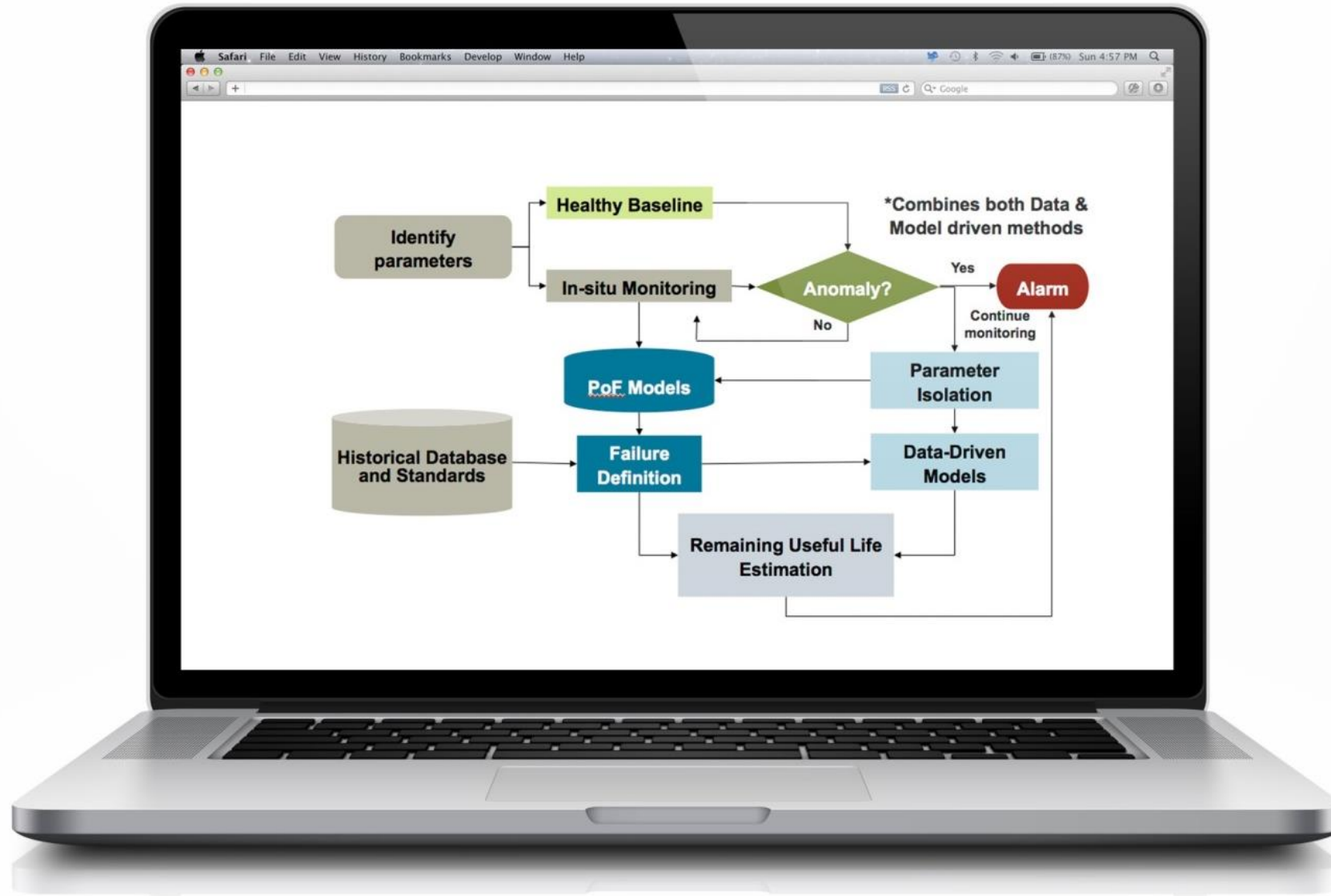
Deliverables

- Design and Development of Built Environment and Energy Infrastructure Modelling (Q4 2017)

- Algorithm development and validation for analysis of Energy Infrastructure and Transport (Q2 2018)

- Creation of Community Coalition Models (Q1 2019)

- Front End Intelligence and Adaptive Controls in DMS (Q3 2019)

- Fusion Prognostics for Network Assets (Q1 2021)

RUL Prediction based on RVM (Starting point 40th Cycle) Battery No.5
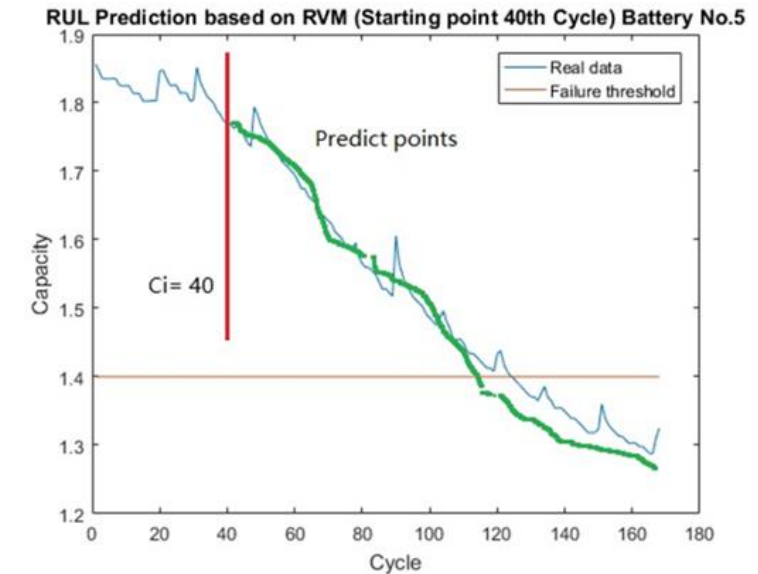
Interface

- WP 1 CRP Aspects: Community Coalitions.

- WP 2 Energy Supply: Supporting Digitising the Energy Network.

- WP 3 Infrastructure and Storage: Lifecycle analysis of storage and DSM challenges and solutions with storage.

- WP 5 Validation and Demonstration: optimisation of front end intelligent-adaptive controls and requirements of varying housing/energy stocks.

- WP6 Multi-Scale Architectures: operational decision support system integration.

- Provision of Data sets

- Revision Control – Manual for Algorithms

- Access to Models

- Energy Demand Workshops

- Technical Reports and Papers

- Operational Decision Support Maps

Resource Plan

- Integration and Connectivity Supporting Co-Evolution
  - **Energy Demand and Energy System Modelling (1x RA, Q1 2017):** how conventional building performance software and energy system modelling can be integrated to achieve a deeper understanding of the energy demand characteristics of the <u>built environment</u>.
  - **Energy Demand Analysis (1xRA, Q3 2017)**: Multi-Agent Systems and Smart Grid Modelling
  - **PhD Studentship (James Watt Scholarship) (1xPhD, Q2 2017)**: Embedded Intelligence within Energy Networks: Front end analysis and adaptive control.

Phil Taylor
WP 5: Validation and Demonstration

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Work package overview, aims and objectives

- Validation and demonstration of multi vector energy systems

- Generate Data

- Feed into models and understanding

- Living labs approach

- Operational insights

Methods, tools and datasets

- Test specific energy system arrangements as a service for the co evolution cycles and work package research

- Link to laboratories and RTDS equipment

- VEEEG Methodology

- Socio Technical approach

Demonstrators

National Centre for Energy Systems Integration

Demonstrator	Key Features
Science Central	Urban, Mixed Use, New Build, Multi Vector, Data Rich
ETI/ESCat Smart Systems and Heat	Urban, Domestic, Retrofit, Heat and Power
Findhorn	Eco Village, Socio Technical
Haringey	Socio Technical Urban Living Laboratory
Thames Valley Vision	Industrial and Commercial Demand Response
Cockle Park Farm	Rural, Farming, Anaerobic Digester, Heat and Power
Customer Led Network Revolution	Storage, Smart Grids, Suburban, Rural, Medium and Low Voltage

Deliverables

- Develop a detailed description of equipment and functionality of each demonstrator

- Develop a description of how to access the site, safety rules, ethics and how to define experiments or data requirements

- Pursue further demonstration sites
  - Hydrogen
  - Gas and Electric combined
  - Isle of Wight

- Carry out experiments, produce data sets (qualitative and quantitative)

- Validated/Calibrated models

- Evaluate control systems

Interface

- Communicate what is possible to Work Packages WP1 - 4

- Receive requests for data/experiments/configurations/interviews

- Conduct experiments

- Generate Data and share

- Facilitate interviews

- Disseminate findings through demonstrators – WP7

- Integral part of co evolution cycles – WP6

Resource Plan

- Two technicians in place (Martin and Roy)
- RA resource (5 RA years in total)
  - Dr Haris Patsios Science Central
  - Dr Simon Blake Cockle Park Farm
- Impact and Engagement Officer (Advert out)
- Industrial Engagement – Dr Sam Neill
- Much of the early work will be preparatory to get the demonstrators fully understood and fully functional
- Real research probably from 18 months in so additional recruitment here will start 12 months into the programme

Any questions?

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The Site as a Living Laboratory

Newcastle University

Science Central Masterplan

Residential

Office / Mixed use

Newcastle University

Energy storage test bed

Geothermal borehole

EV Filling station

Smartgrid Electrical Infrastructure (11kV/400V)

Sustainable Urban Drainage Lab and demonstrator
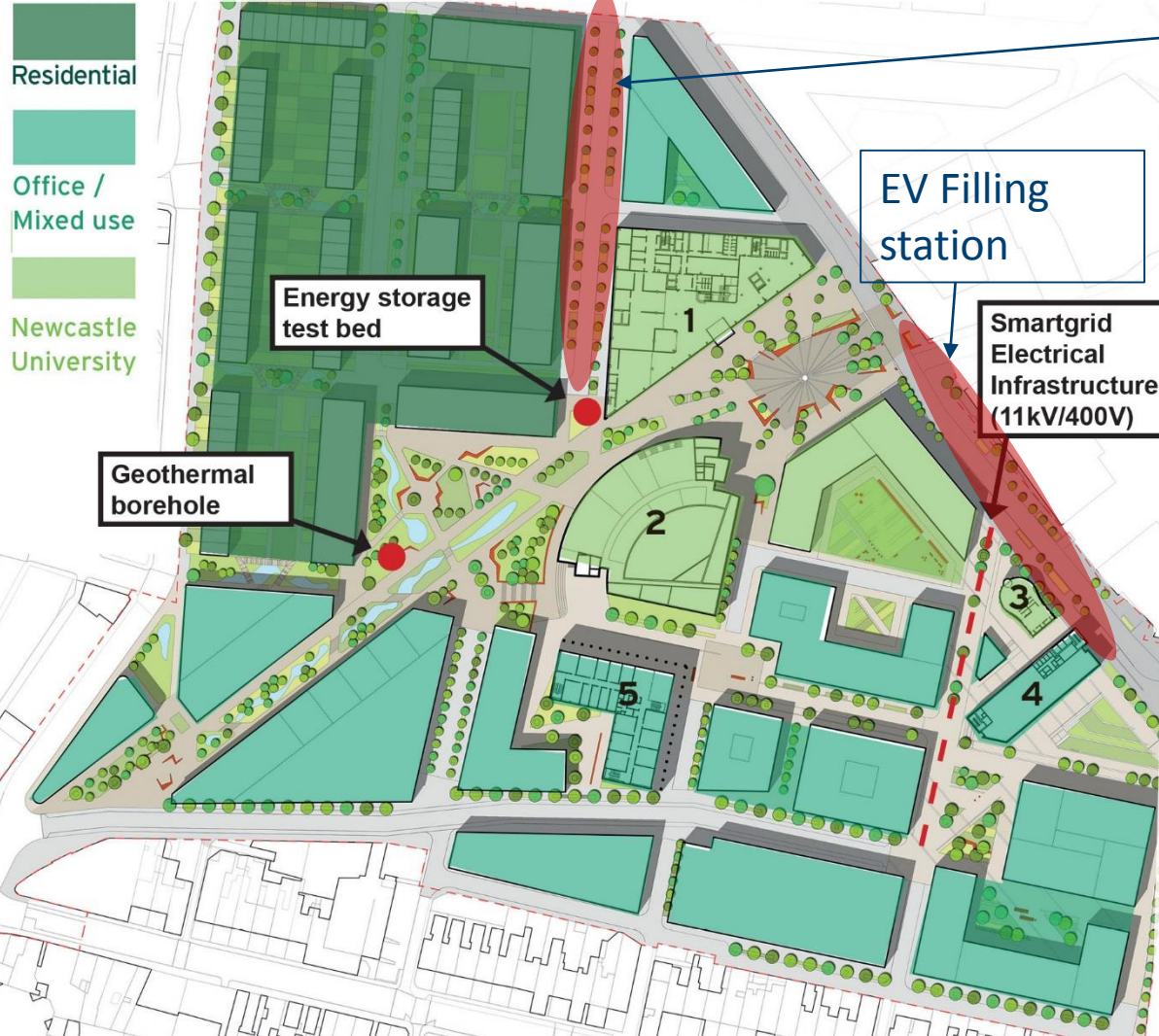
1) Urban Sciences Building
Completion date: Autumn 2017

2) Learning & Teaching Centre
Completion date: Autumn 2017

3) The Key
Completed: February 2016

4) The Core
Completed: November 2014

5) Newcastle Laboratory
Completion date: Spring 2018

NASI
NISDI
UKCRIC

ETI/ESCat SSH

L&G Investment

Cockle Park Farm – AD – CHP + Storage

Energy production opportunities

1. Phase converter/grid interface unit
2. PV generation
3. PV cell test site
4. Air source heat pump
5. CHP generation

— — Electric grid
— — Heat network

Energy storage opportunities

1. Electrical storage
2. Thermal energy storage

Heat demand
Cooling demand

Cockle Park Farm
Facilitating rural energy for tomorrow

Newcastle University

Institute for Sustainability

National Centre for **Energy Systems Integration**
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Grid

Second life EV batteries

Single to three phase converter

Cows

Anaerobic Digester

Power

Pigs
Unique pig finishing barn.

CHP
Supplies energy needs for buildings and facilities on the farm.

Heat Network

GIS
Geographic information system gives overview of farm - collects data
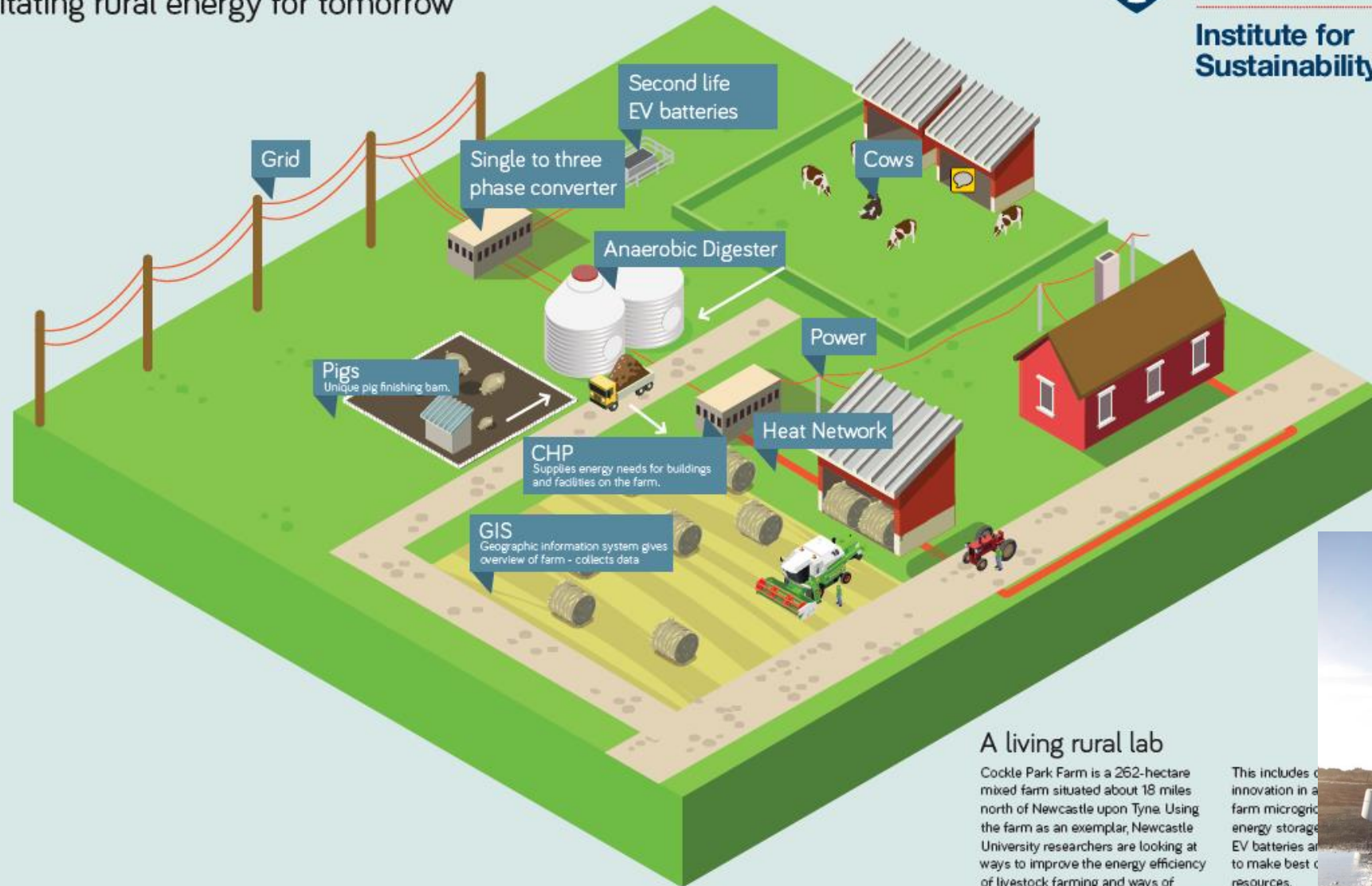
A living rural lab

Cockle Park Farm is a 252-hectare mixed farm situated about 18 miles north of Newcastle upon Tyne. Using the farm as an exemplar, Newcastle University researchers are looking at ways to improve the energy efficiency of livestock farming and ways of generating additional energy from the farming processes themselves.

This includes innovation in a farm microgrid energy storage EV batteries a to make best of resources.

Design by AlphaGraphics
© Newcastle University 2016
The University of Newcastle upon Tyne trading as Newcastle University.

Professor Gareth Harrison
Multi-Scale Architectures, Planning and Operation

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University of Edinburgh

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Work package overview, aims and objectives

- **Aims**
  - Develop the whole system 'planning' tool for use in the co-evolution cycles
  - Integrate models and scenarios and generate 'plans' for system co-evolution, ensuring operational characteristics, interdependencies, uncertainties and governance are appropriately captured
  - Tool used interactively to explore assumptions, approximations and uncertainties in the models
- **Objectives**
  - Co-develop accurate intra-day operational models and 'shortcut' planning models that are systematically 'calibrated' and uncertainty quantified
  - Framework for handling uncertainty and quantifying accuracy/robustness of whole system 'plans'
  - Framework for solving multistage system plans that account for uncertainties and generate robust plans and enable investment decisions to be timed optimally
  - Create a modular 'plug-n-play' framework for large stochastic optimisation and whole system operational and planning problems

Methods, tools and datasets

- Deployment of common datasets with other WPs and employ detailed modelling tools

- Key aspect is a systematic approach to 'simplifying' complex models that preserve critical features and understand the implications

- The multi-stage planning framework will be developed progressively

- Currently the approach envisaged is:
  - formation of a library of scenarios, reduced scenario tree, and conditional tree using stochastic programming;
  - test plans on a wide range of scenarios, and identify significant 'stress' scenarios

- Statistical emulation which removes the reliance on a particular set of scenarios through interpolation between them

Deliverables

- WP focus is very much on ensuring three co-evolution cycles are as useful as possible – the first in 18 months time

- Main deliverables will be a framework into which models of components can be integrated

- 'Working versions' of shortcut models will be become progressively more refined as time progresses

- Initial burst of activity to examine interfaces between components as data and modelling interface is needed early on in project

Interface

- Clear 'natural' interfaces will be developed with WPs 2, 3 and 4 to allow exchange of sub-models at different spatial and time resolutions

- These interfaces are essential for understanding the potential for distributed control and support/balancing services

- Substantial effort to ensure social and economic constraints and considerations feed forward from WP1

- There will be substantial 'co-development' of models with major effort on calibrating 'shortcut' models against detailed models

Resource Plan

- Resource:
  - Currently allocated 8 person years across UoE, DU and NU
  - Require an initial burst of activity followed by sustained co-development with specific WPs
  - Aiming for an outline capability by time of first co-evolution cycle (18 months)
- Engagement will be critical to achieving this:
  - Initial mapping of interfaces between system components
  - Identify detailed need for understanding of roles and working practices of key actors (e.g. electricity and gas SOs)
  - Looking to briefly embed researchers with key actors to achieve this

Any questions?

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