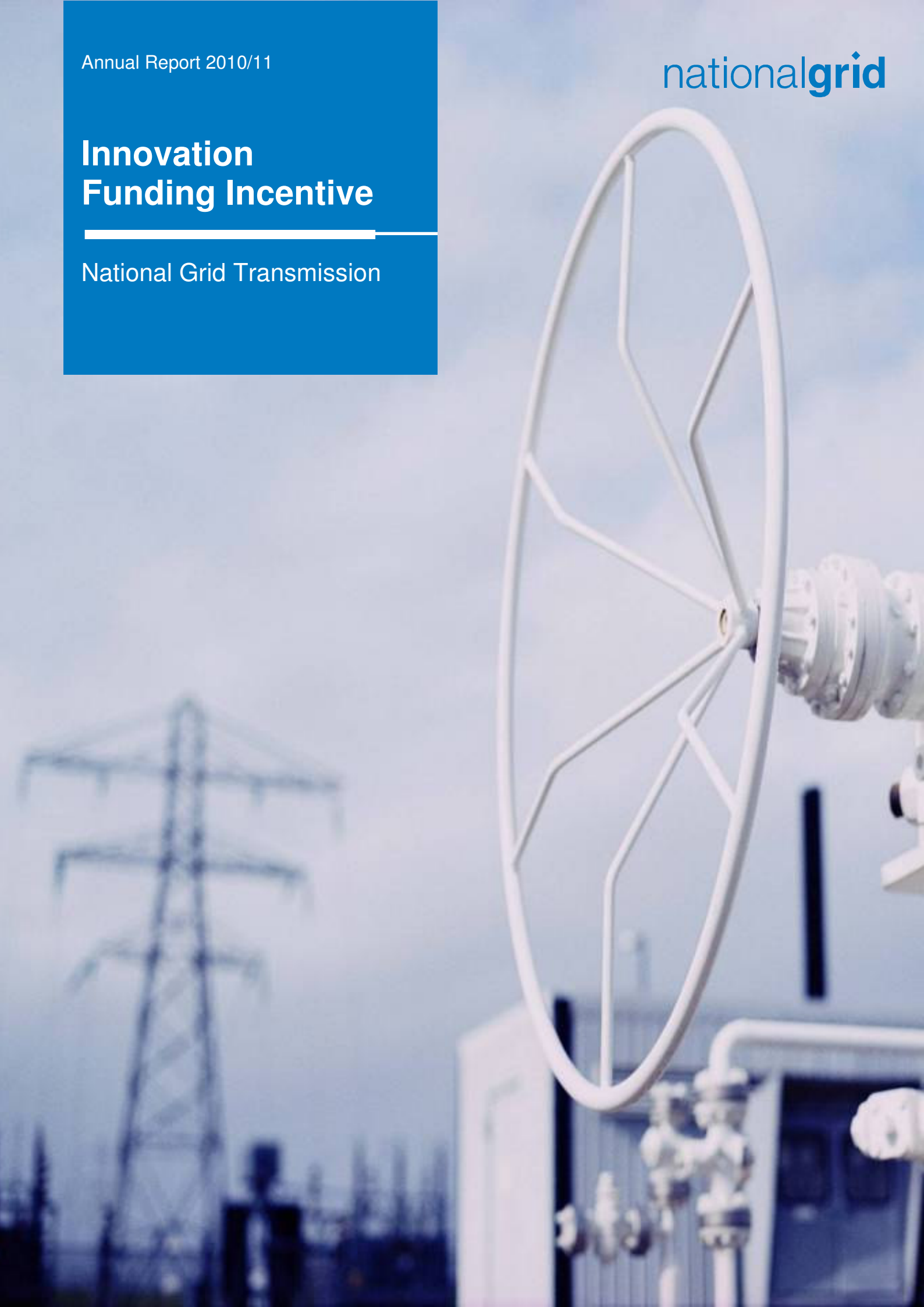
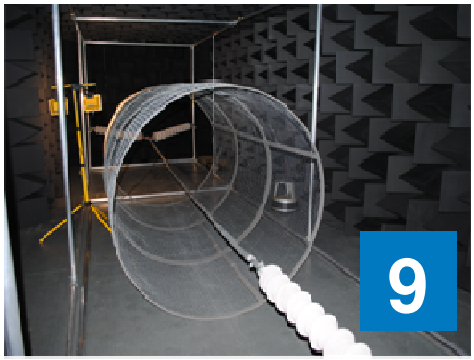
Annual Report 2010/11

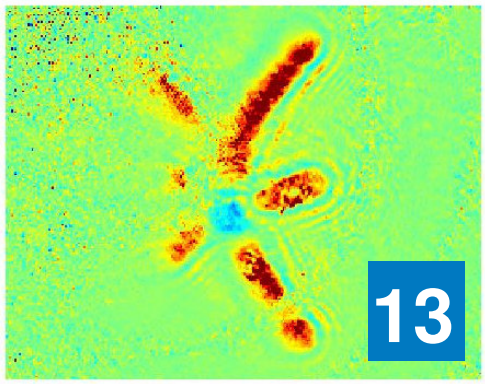
Innovation Funding Incentive

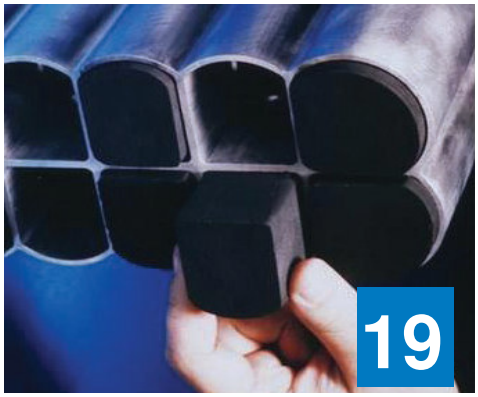
National Grid Transmission

nationalgrid









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National Grid

National Grid owns and operates the high voltage electricity transmission system in England and Wales and operates the Scottish high voltage system. National Grid also owns and operates the Gas Transmission system throughout Great Britain. Through its low pressure Gas Distribution business, National Grid distributes gas to approximately eleven million businesses, schools and homes

> “National Grid maintains an operational reliability of 99.99998%”

Electricity Transmission

National Grid owns and maintains the high-voltage electricity transmission system in England and Wales, together with operating the system across Great Britain, balancing supply with demand on a minute by minute basis. There are over 9,000 circuit miles and 337 substations at around 240 sites.

Gas Transmission

National Grid owns, maintains and operates the national gas transmission system in Scotland, England and Wales, balancing the flow of high pressure natural gas between import terminals and the regional gas distribution networks, gas storage facilities, international interconnectors, power stations and other large industrial customers.

> “The NTS consists of 4,300 miles of high pressure pipeline”

Introduction from Nick Winser

Welcome to this report covering the fourth year (2010/11) of National Grid's Transmission Innovation Funding Incentive (IFI) R&D program.

2010/11 has been another good year for the IFI programme, building on the success of previous years, through successful collaborations and supplier relationships to deliver significant impact and therefore benefit to the consumer. The IFI program has continued to add customer value to the transmission networks by driving innovation in key areas such as the mitigation of climate change, managing an ageing asset fleet and understanding the future challenges to the networks with uncertain demand and supply throughout the UK. National Grid is committed to being an innovative leader in energy management and safeguarding our global environment for future generations, a step change in innovation is required to deliver the future energy networks and safeguard our global environment.

In Gas Transmission we have continued to research alternatives to venting and investigated compressor reconfiguration to provide increased environmental benefit whilst maintaining security of supply. We have also has continued research into the mitigation of stranded assets, primarily by investigating the feasibility for the reuse of part of the existing network in a Carbon Capture and Storage System.

In Electricity Transmission, we have built on our strategic relationships with key universities to build knowledge for utilisation both in innovation projects and directly in support of the management of our assets. Our support and participation in EPSRC, TSB and EU grants showcases our commitment to developing academia as well as expanding our links to energy centers for doctoral training where appropriate. National Grid has continued work on live line working as well as researching the standardisation of secondary systems in substations using IEC 61850. We have also continued promising work on alternatives to SF6 by partnering Liverpool University with EPRI ensuring the support can be maintained and funding increased in this area.

The Innovation Funding Incentive is a vital tool to assist in addressing the challenges that National Grid now faces. The current IFI programme has focused on existing components and assets. This focus while providing demonstratable customer value is a relatively small-scale commitment in funding and is limited in the potential customer benefit. The broader range of future funding that has been identified through RIIO should enable a wider range of complex systems and applications to be developed and trialled increasing customer value in the Gas and Electricity transmission networks. To enable the delivery of a Low Carbon energy market by 2050, innovation is needed in key areas including the aggregation and despatch of demand response, deployment of smart technology, increasing the network capacity, introduction of smart energy grids and the stricter management of gas quality with changing future supplies. These are some of the areas where National Grid will focus innovation funding in the coming years.

In 2010/11 National Grid spent £2.7m on Gas Transmission R&D and £6.1m on Electricity Transmission R&D. This is virtually 100% of the available allowances. National Grid believes strongly that where possible our R&D should be collaborative, allowing us to maximise our funding and share the benefits with our partners. With this in mind the value of the 2010/11 R&D portfolio is in excess of £90m.

The following report gives an overview of some of our R&D focus areas as a snapshot of our strategic R&D suppliers, as well as detailed information regarding our R&D programme. I hope that you find it both informative and interesting.

Nick Winser,
Director National Grid UK

Overview of 2010 / 2011 programme

The fourth year of the Innovation Funding Incentive (IFI) has again been very successful. In Electricity Transmission the renegotiation of the framework agreements held with our four key universities shows National Grids continuing commitment to not only innovation but also to ensuring skills within the industry.

In addition to working with key universities in the UK, National Grid has hosted visiting students and professors from Aalto University and the University of Graz as part of a Framework 7 project and currently has students in placements from Imperial college and the University of Strathclyde.

Gas transmission has continued to work closely with Germanischer Lloyd Noble Denton (GLND) working on a series of high profile projects

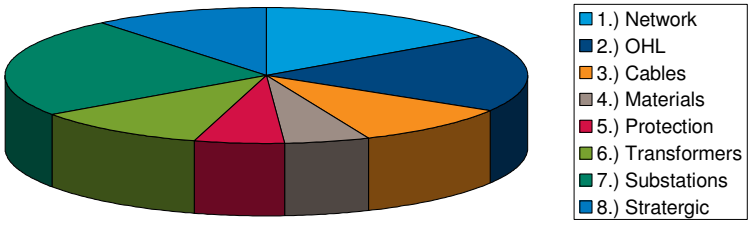
Our aim is to create a balanced portfolio to improve efficiency, improve asset and energy management and support the environment.

There are 122 live projects detailed in the latter stages of this report. The projects are split into 93 Electricity Transmission projects and 29 Gas Transmission projects, these projects are split over the different assets on their respective networks. This split is demonstrated in the pie charts on the opposite side of this page.

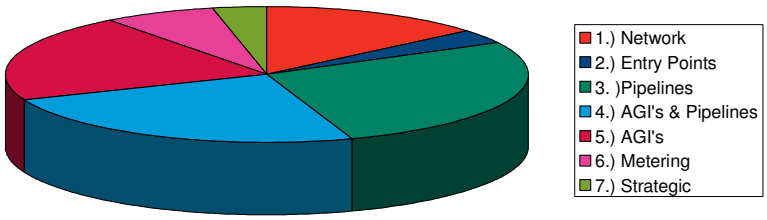
Detailed project breakdowns provided later in this report provide summaries of the individual project aims, details costs to date, expected future costs, expected timescales and provide a brief progress report as well as outlining the benefits we aim to achieve through each project.

We continue to have clear governance and visibility of our plans at executive level.

Electricity IFI Portfolio

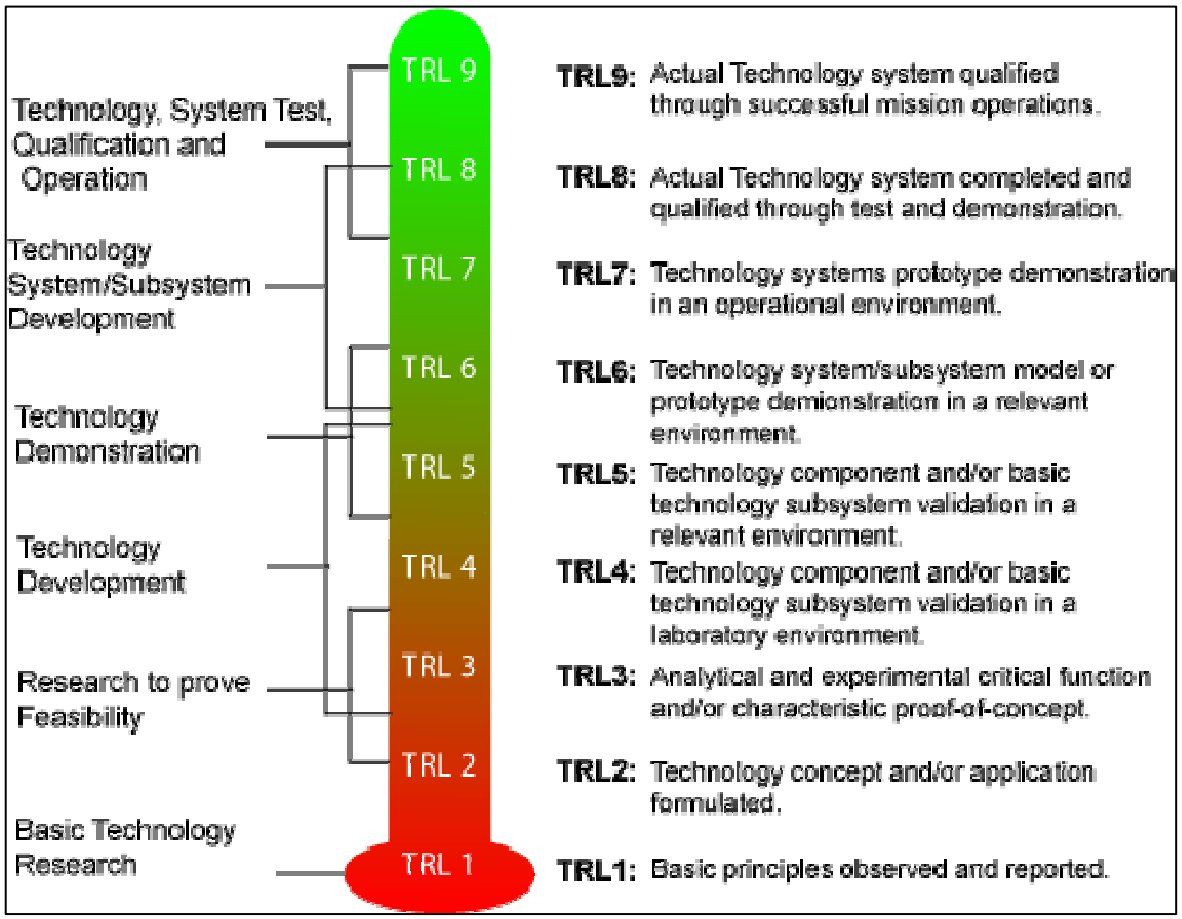


Gas IFI Portfilio



Programme Focus Areas

As part of this report National Grid would like to highlight the broad range of challenges and ideas that currently make up our innovation portfolio. The portfolio covers projects at all stages of development and technical maturity. In order to highlight the different levels of maturity that we are currently exploring, all the areas mentioned in the foreword will have an indication of their technology readiness level (TRL).



The TRL indicates how close a technology is to becoming both technically and commercially viable and can be seen in Figure 1. The bottom level on the TRL, Level 1 relates to research with no obvious purpose more commonly known as “Blue Sky Research”, Level 9 on the TRL scale indicates products/information readily available with no development required. Currently National Grid’s R&D activities have been focussed between TRLs 2 and 8. This range ensures that National Grid balances both tactical and strategic projects within its portfolio but also ensures that the innovation money is being used for innovation activities and not purchasing existing solutions. However demonstration projects (TRL 7-8) tend to be of higher cost and funding resections have limited the impact we would have wished in this area.

The projects highlighted in the following pages will illustrate the differences between the TRLs and will also illustrate National Grid’s continuing approach to maintaining a balanced portfolio of Research and Development.

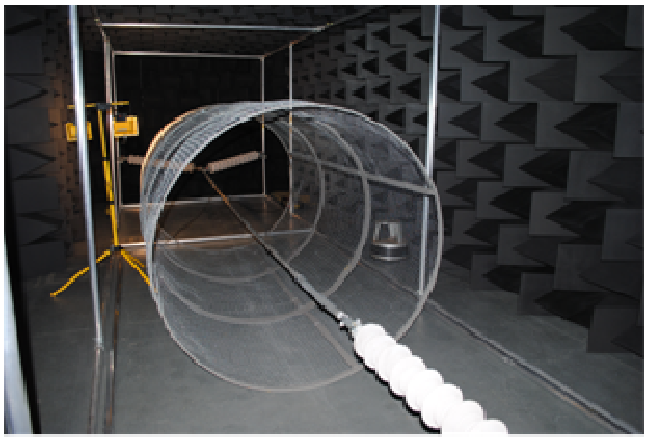
Focus on Electricity Innovation

The University of Manchester

Focus	: Strategic
TRL	: Range 3-7
Benefits	: Project Dependent

National Grid has a framework agreement in place with four universities across the country specializing in areas that are key to National Grid. The framework enable research and development to be agreed and started in an efficient manner. There are currently 9 projects active.

The University of Manchester has supported National Grid in a diverse range of projects over the past year with work taking place across a broad range of technical areas. Much of the work carried out uses the suite of high voltage experimental facilities developed jointly with National Grid.

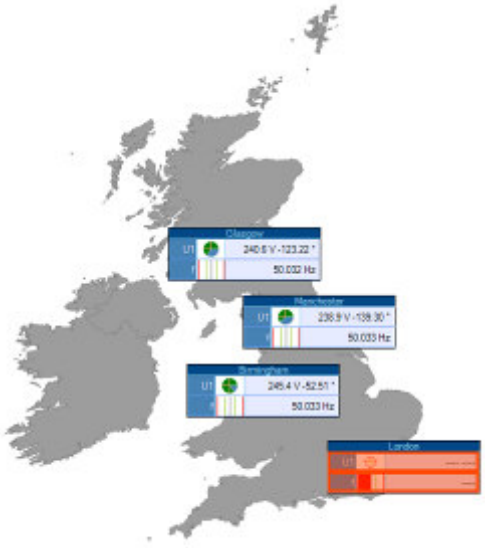


Significant amounts of work have been carried out on overhead lines on a number of projects relating to composite insulators, overhead line noise, live line working and composite cross-arms. The composite cross-arm project team has successfully installed four prototype cross-arms at a location in the Cairngorm Mountains – a process that has identified a number of techniques that could be used to enhance the installation process. The cross-arms are placed on a 132kV line and the way in which snow and ice accrete on the cross-arms is being studied giving vital information about how these will perform in comparison with standard insulators. Later this year, the cross-arms will be trialled in a coastal location and energised with a 231kV transformer (231kV being the phase to earth voltage of a 400kV system). The live line activity has examined the overvoltages that could be present on the National Grid transmission system and these have been translated into safe distances that must be maintained by workers in phase to earth and phase to phase gaps. This simulation work has been carried out alongside testing work in the high voltage laboratory that has examined the performance of various types of rope for use in live line working.

A theme of environmental enhancement of equipment continues to be a key part of our work. In transformers, work has been focused on studying electrical breakdown and streamer propagation in alternative liquids under lightning impulse voltage and partial discharge characteristics under ac voltage in oil gaps or along oil/solid interface. Using mineral oil as a reference, synthetic esters and natural esters are being studied. The work that is being carried out suggests that alternative liquids in transmission voltage transformers are a realistic prospect. Work is also being carried out to further assess promising alternatives to SF6 insulation for busbar structures including insulating foam and CF3I. Elimination of SF6 would help manage greenhouse gas emissions. CF3I is a promising material in theoretical studies although the boiling point may compromise its use in certain low temperature environments. Insulating foam has also been tested in the high voltage laboratory using both AC and lightning impulse voltages.

Manchester is also supporting National Grid in the future roll-out of new technologies such as HVDC and dynamic thermal rating. Mike Barnes from Manchester has been working closely with colleagues at National Grid to identify the key challenges with the deployment of multi-terminal voltage source HVDC. In addition, research projects have examined the effect HVDC will have on overall system dynamics. One project is examining wide area measurement system (WAMS) based power oscillation damping (POD) controllers acting through VSC-HVDC links. Simulations were performed first on a small test system (as a proof of concept) and then on a larger, more heavily meshed, network where the damping through VSC-HVDC active power modulation was shown to be extremely effective at stabilising the whole network. Work is also examining the scenarios which can lead to sub-synchronous resonance in meshed power networks with relatively short but heavily compensated lines operating in parallel with HVDC lines. The work is examining AC/HVDC topologies that can minimise the exposure to sub-synchronous resonance. Finally, a project is examining the system benefits that could result from the combined use of quadrature boosters and dynamic thermal rating. The optimisation of these controls would enable better utilisation of existing facilities and therefore reduce the demand for new investments

In another project that could have implications for utilisation of power system equipment, work is developing improved thermal models for transformers using computational fluid dynamic methodologies. By linking the output of thermal modelling with information gathered from records and experimental sampling of transformer insulation, better forecasts of transformer life will result.



Manchester provides National Grid with technical support on a variety of Protection and Control (P&C) projects designed to enhance the reliability, stability and security of the transmission grid. The activities will help National Grid adapt their existing P&C strategy to the challenges and opportunities created by series compensated lines, DC interties, renewable and intermittent energy sources, new generation profiles, dynamic demand, wide area synchronised measurement systems, high data rate communications, emerging technologies and consumers expectations for higher reliability and non-intrusive affordable energy.

Projects on “Collapse Prediction”, “Wide Area Monitoring, Protection and Control (WAMPAC)” and “System Integrity Protection Schemes (SiPS)” will help ensure the UK can connect sufficient renewable and low carbon energy sources to satisfy our 2020 and 2030 carbon reduction targets. One of the projects involves the design of an optimal strategy for introducing and building a WAMPAC system; this extended the outcomes of an EPSRC funded FlexNet Wide Area Monitoring System and is now being used to assess the dynamic performance of the grid. New techniques for implementing wide area based SiPS are also being investigated, these are designed to ensure the grid can operate reliably when the generation profile changes to include fewer synchronous machines, significant numbers of DC interties, more intermittent sources of renewable generation, increased loading of lines and the use of FACTS.

A project related to the “Architecture of Substation Secondary Systems (AS3)” involves the design of an optimal substation secondary system based on a set of golden rules. Tests have confirmed that the architectures are realistic for reliable, dependable and extendable secondary systems with simple, standardised and long life P&C interfaces with merging units from different manufacturers. The project also involves an investigation into the impact of merging units on protection schemes designed in accordance with the IEC61850 standard.

Improved knowledge on the harmonic behavior of the transmission network may assist in the deployment of power electronic based technologies such as HVDC and FACTS. A project has resulted in the development of a test bed for assessing the frequency response of conventional and non-conventional Voltage Transducers (VT).

Focus on Electricity Innovation

The University of Strathclyde

Focus	: Strategic
TRL	: Range 3 - 7
Benefits	: Project Dependent

National Grid has a framework agreement in place with four universities across the country specializing in areas that are key to National Grid. The framework enable research and development to be agreed and started in an efficient manner. There are currently 6 projects active with the University of Strathclyde

Strathclyde – National Grid Research Workshop

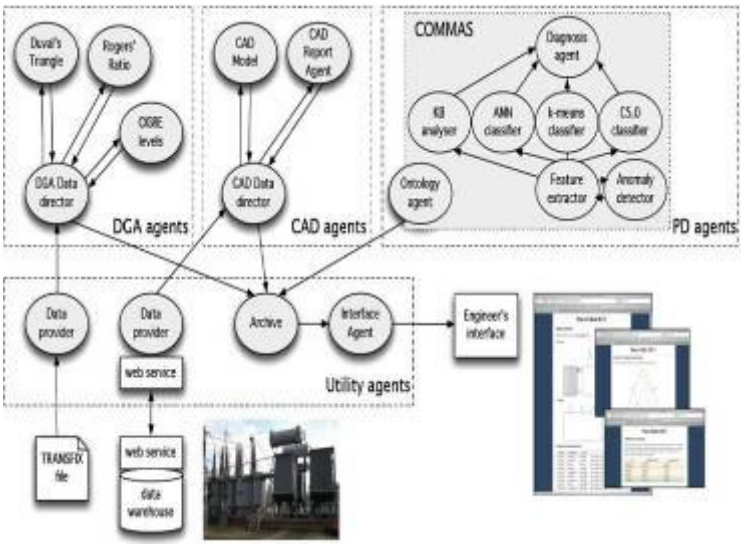
To coincide with the establishment of the new Framework Agreement, actions are being taken by both the University and National Grid to escalate the strategic R&D partnership. A workshop was held at National Grid House, Warwick on 6 May 2011, at which a delegation of senior staff from Strathclyde (including the Directors of the Institute for Energy and Environment, the future Head of Department, and research group leaders) met with about 20 National Grid staff. The meeting included breakout sessions to discuss specific research themes of particular and timely relevance to future network challanges.

Analysis of CBWatch-2 Circuit Breaker Monitoring Data

The project aimed to investigate the potential for circuit breaker health monitoring through analysis of data from the CBWatch-2 system. From the full set of CBWatch-2 collected data, the key parameters were found to be SF6 gas density, cumulative wear, and opening times, with some relationships found between these parameters and breaker health. In particular, gas density degradation was modelled using linear regression, and a tool for prognosing remaining time to lock-out was created. Recommendations for improving the accuracy of CBWatch-2's calculation of density were determined. Additionally, clustering of breaker opening time revealed strong family and individual trends, highlighting the potential for early warning of anomalous behaviour.

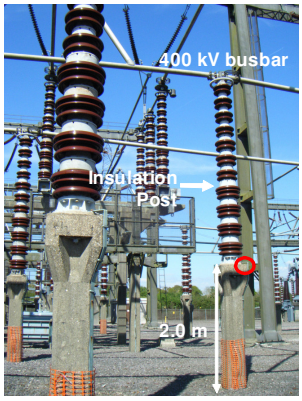
EPSRC Supergen 5 AMPerES Transformer Monitoring Demonstrator

This project involved the installation of a range of sensors on two end-of-life transformers at Elland substation. Over 50 parameters were measured, including externally mounted temperature and vibration sensors; internal temperature, moisture, and dissolved gas; and environmental weather and load. This data was available to Supergen 5 academic partners through an on-line data warehouse interface, allowing immediate access to measurements captured every five minutes. Strathclyde created an architecture for automated analysis of this data using multi-agent systems technology. This allows new analysis algorithms and data sources to be flexibly integrated while the system is running, using standards-based messaging between agents. The messaging data format was constructed based on the Common Information Model, allowing future integration with other CIM-based data stores. Deployed in this architecture, Strathclyde developed a suite of anomaly detection modules to automatically detect anomalous transformer behaviour. A novel technique was used to reduce the possibility of false positives in the case of unusual environmental conditions. These modules detected no instances of unusual transformer behaviour, but identified 21 cases of sensor or data logging error.

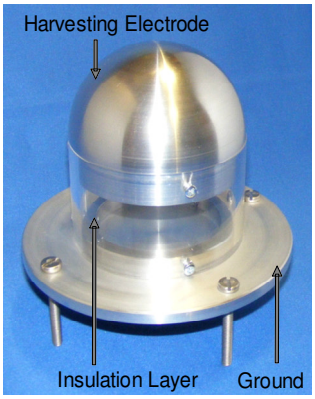


Energy harvesting technology for self-powering condition monitoring sensors

Investigation and development of energy harvesting devices based on capacitive / inductive coupling with the electromagnetic fields inherent within electricity transmission substations. The aim is a generic technology capable of powering substation light current equipment such as active sensors that monitor the status, health and condition of electrical plant. A trial application of the technology to power wireless sensors for short-distance data transfer for the condition monitoring of HV equipment at substations is being undertaken.

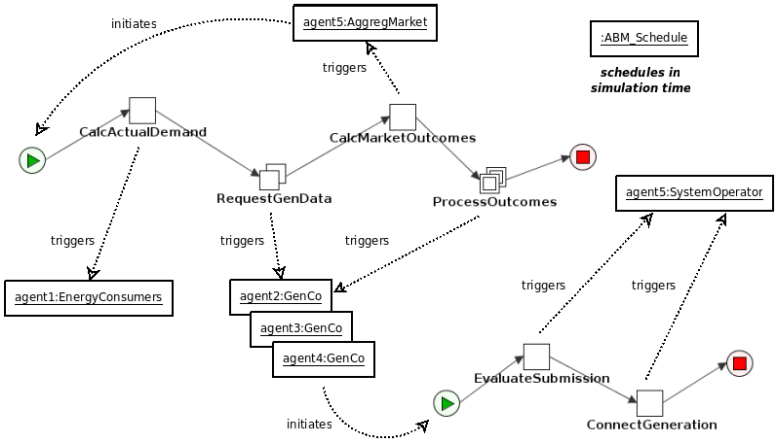


Survey of ambient electric field levels in an outdoor 400 kV substation



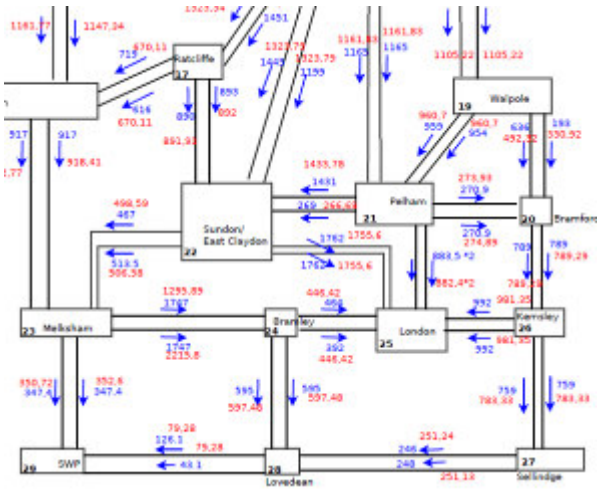
Demonstrator hardware for capacitive energy harvesting demonstrator to power a wireless sensor

SuperGUM



Development of a prototype software analysis program by University of Strathclyde for probabilistic generation planning, for eventual use by National Grid. The software developed will be available as a prototype analysis tool, and National Grid will benefit form the knowledge gained during the project. The software could be developed into a production tool used in gaining a greater understanding of the generation market, and in the assessment of risk in load-related capital planning.

Example of representation of the process by which a generator applies for and obtains a connection to the Transmission system and, by so doing, becomes part of the generation background.



SUPERGEN FLEXNet Consortium - Representative model of the GB transmission system

Suitable environments are needed that sufficiently test new ideas and allow study of phenomena without overwhelming a researcher with excessive data or obscuring the relevant phenomena. A new model to represent the GB transmission system has been developed to facilitate that. A “representative” model of the electricity transmission network in Great Britain (GB) has been developed at the University of Strathclyde during late 2010 with the purpose of serving as a test system for a number of studies where use of a complete model of the GB transmission network is either not possible or not useful. The model is based on and has been validated against a solved AC Load Flow reference case that was provided by National Grid Electricity Transmission (NGET).

Focus on Electricity Innovation

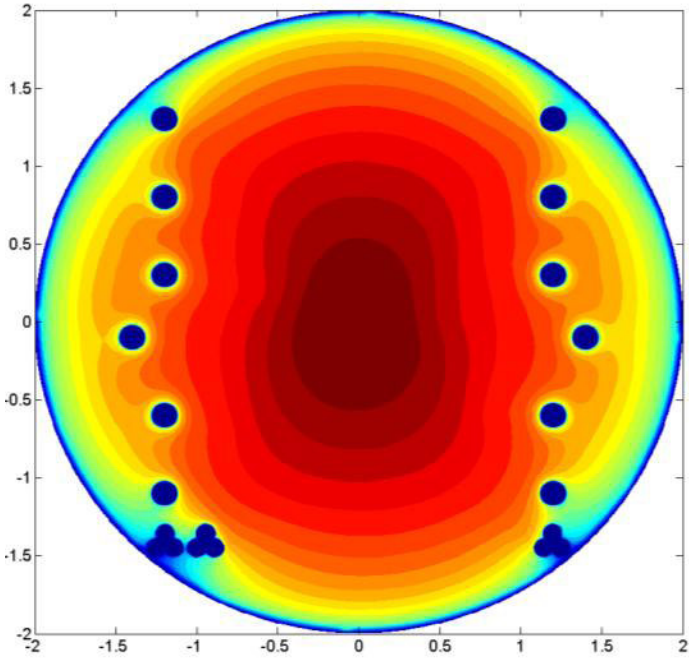
The University of Southampton

Focus	: Strategic
TRL	: Range 3 - 7
Benefits	: Project Dependent

National Grid has a framework agreement in place with four universities across the country specializing in areas that are key to National Grid. The framework enable research and development to be agreed and started in an efficient manner. There are currently 7 projects active with the University of Southampton

Ratings of Cables in Tunnels (ROCiT)

The thermal rating of a cable is the maximum current that can flow through the conductor without the cable over-heating. Ratings needs to be calculated accurately since a pessimistic estimate makes poor use of an expensive asset, but over-optimism can lead to premature ageing and failure. Improvements in the cost and availability of computational power in recent years have led to numerical techniques such as finite-element analysis (FEA) becoming viable for cable-rating calculations. For cables in tunnels we have combined FEA with computational fluid dynamics to model the air flow and estimate cable temperatures and tunnel ventilation requirements.



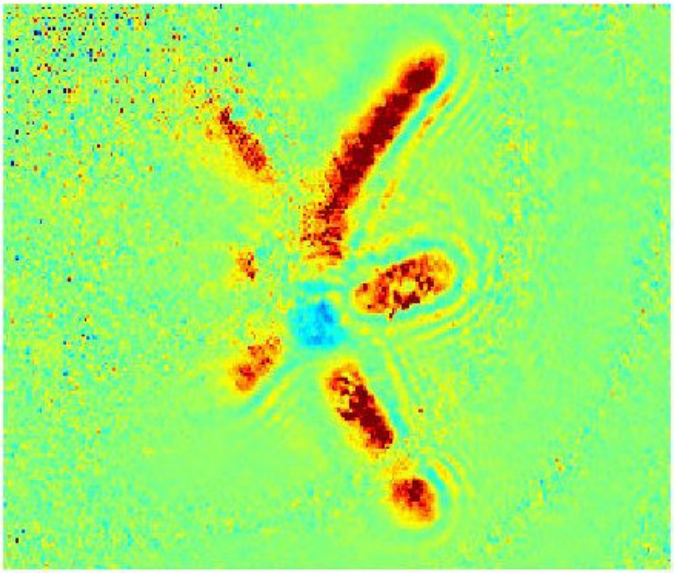
Contours of air velocity within a cable tunnel showing higher velocity in the centre of the tunnel, but reduced air flow near to the cables and tunnel walls

The mathematical modelling is verified by air flow measurements taken in National Grid tunnels.

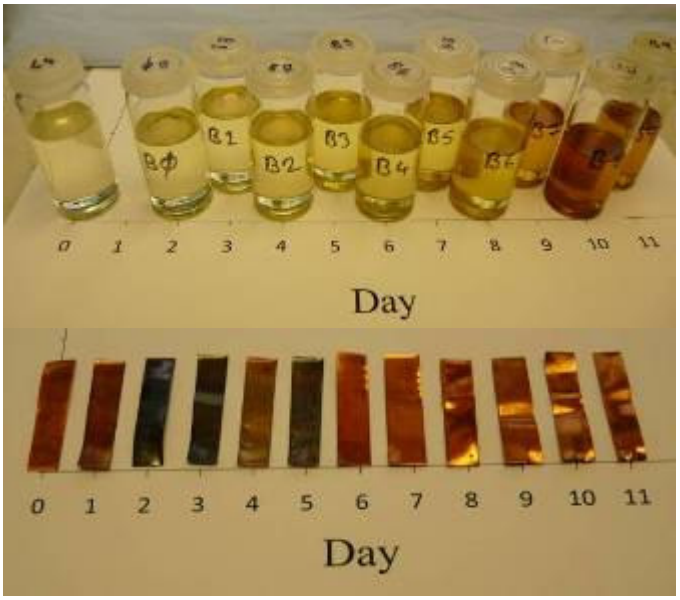
The results of this research are already being applied within National Grid to define refurbishment requirements in the Medway and Tilbury tunnels. There are also benefits at a strategic and planning level. For instance, it has proved possible to evaluate the commercial benefits from co-locating more cables in one tunnel to make optimum use of tunnel assets.

Charge deposition on insulators

The accumulation of charge on insulator surfaces causes field distortion and can initiate flashover. For this reason, it is common practice to avoid subjecting equipment such as gas-insulated switchgear (GIS) to dc electric fields.
The build-up of charge on an insulator can be observed and quantified using the Pockels technique. This makes use of the fact that when light passes through certain crystals its polarization is influenced by the local electric field.



The Pockels technique offers a good method of capturing the dynamics of charge build-up and surface discharge while simultaneously quantifying the charge density. The charging characteristic of insulators in air and N2/SF6 mixtures have been studied at a range of pressures. From the results we have produced a model to predict the dynamics of charge accumulation and movement over the dielectric surface.
This is a Pockels image of positive charge (red) and negative charge (blue) on the surface of an insulator. The image size is approx. 13 x 11 mm.



Progressive change in colour of copper strips with ageing in oil at 150℃

Corrosive sulphur in transformer oil

The formation of corrosive sulphur in transformer oil and the resulting deposits of copper sulphide in the paper insulation have caused a number of large transformer failures worldwide (including Lackenby SGT4). Further transformers will have to be replaced early because of this problem.

The degradation mechanism is poorly understood and hence diagnosis is difficult. A preliminary study has been completed at the University of Southampton. This has shown that x-ray fluorescence and x-ray spectroscopy are potential methods for detecting the onset of degradation and tracking its progress. Copper aged in transformer oil changes colour. The colour is related to the surface thickness of sulphide deposited and is correlated with the depletion of corrosive sulphur (dibenzyl disulphide). Further work in underway to examine the likely long-term effectiveness of National Grid's mitigation strategy (passivation) and to develop condition assessment techniques for the large number of 'at risk' transformers on the network.

Focus on Electricity Innovation

The University of Cardiff

Focus	: Strategic
TRL	: Range 3- 7
Benefits	: Project Dependent

National Grid has a frame work agreement in place with four universities across the country specializing in areas that are key to National Grid. The framework enable research and development to be agreed and started in an efficient manner. There are currently 3 projects active with the University of Cardiff.

Areas of Research

Research at Cardiff over the past few years has concentrated on the following areas: a) earthing systems, risk assessment and safety, b) Transient modelling of transmission networks, overvoltage protection and insulation coordination, including the impact of connecting offshore wind farms, c) compact substations and uprating of overhead lines.
Furthermore, short projects on: induced voltages and currents on overhead lines and shunt reactor and MSCDN transients were undertaken.
For some projects, co-funding was obtained from EPSRC, Scottish Power and other industrial partners.

Significant research is also carried out at Cardiff on outdoor insulators but with funding from EPSRC and other sources.

Highlights of research outcomes and impact

a) Better understanding of earthing systems and new techniques have been developed for measurement of earthing systems. In close collaboration with National Grid and Scottish Power, a novel variable-frequency technique for the measurement earth impedance of tower lines and substations has been developed involving injection of currents outside the mains frequency to avoid interference. The method is now adopted by National Grid to replace the technique of dc resistance measurement, enabling more accurate measurement of safety voltages and development of prize-winning robust modelling to account for factors influencing accuracy. The experience gained in measurement and modelling allowed the Cardiff group to develop new prize-winning procedures to assess safety of electrical systems using probabilistic approaches The work is now being adopted by National Grid and Scottish Power, and is being implemented as part of National and international standard, through committee membership of Cardiff and National Grid staff.

b) Recent work on transient modelling the impact of offshore networks on the transmission grid has supported National Grid's assessment of insulation coordination aspects when connecting a large offshore wind farm. This work has demonstrated the benefits of overvoltage protection. A current PhD project investigates aspects of future connections scenarios. It is proposed that measurements should be conducted in the near future to validate the predicted modelling levels of overvoltage.

c) Work on substation compaction has led to proposals to reduce the footprint of air insulated substation bays by more than 50% using novel delta and vertical configurations of busbars. Reduced air clearances were proposed in conjunction with appropriate choice and location of Zinc Oxide surge arresters. Furthermore, optical voltage and current measurements help to reduce the bay length.

d) EPSRC-funded research on uprating of overhead lines, which was also supported by National Grid and 6 other industrial partners, led to the development of procedures has enabled optimisation of power transfer capability of overheadlins with minimum changes to structures. Proposals were made to uprate the 275kV, L3 tower lines to 400kV, using surge arresters and polymeric insulators but without structural modifications to the towers.

e) Work on induced currents and voltages on overhead lines helped the revision of NSI4 and the assessment of new low-sag high temperature conductors such as AAAC conductors.

f) Work on **outdoor polymeric insulators** has led to development of new pollution-testing procedures for polymeric insulators that are now included in CIGRE brochures. Furthermore, the work in this area has led to a patent of textured surface for insulators. This is now being further developed through an EPSRC grant

Focus on Electricity Innovation

Life cycle Costing

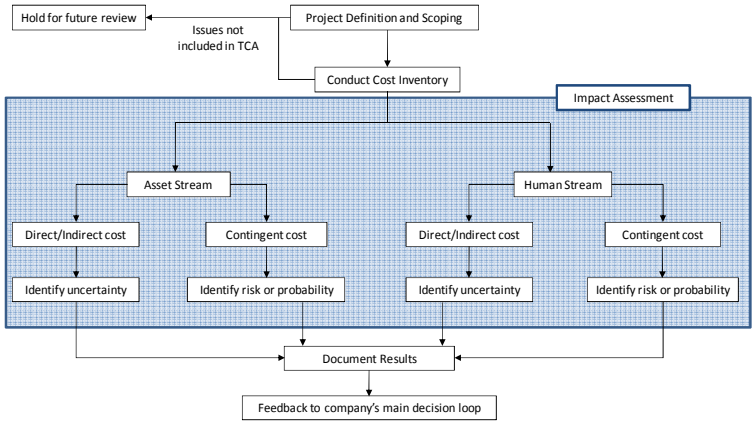
Focus : Asset Management
TRL : 6
Benefits : Innovative approach to life cycle costing, investment and planning.

This National Grid funded paper and poster was presented at CIRED conference in Frankfurt Germany. The conference ran between the 6–9 June 2011

New Life Cycle Costing and Risk Approaches to Asset Investment and Planning

Introduction

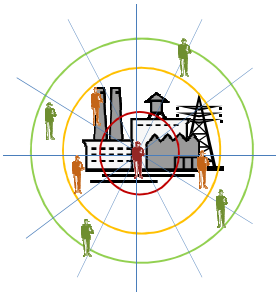
A new integrated life cycle costing (LCC) and risk assessment methodology has been developed which addresses whole life costs. The approach was developed to support asset investment and policy to enable optimum solutions to be identified. It takes into account economics, environmental performance and carbon accounting, health and safety and social costs, with explicit account of risk. The method can incorporate a wide range of cost types in order to obtain an understanding of whole life performance.



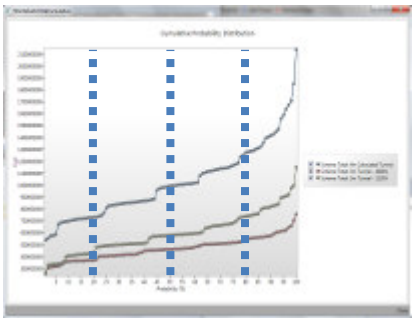
Tool features and benefits

The schematic illustrates the approach to whole life assessment, which examines impacts and costs associated with Assets as well as People. It incorporates direct/indirect costs and contingent liabilities with allowance for uncertainty in values. Contingent costs related to probabilistic events, such as failures or disasters can also be included.

Use of **hazard zones** allows the consequences of failures to be explored for both assets and people dependant on location and vulnerability



Carbon accounting accounts for both embedded carbon in assets, and also in operation.



The use of **Monte Carlo assessment** allows the visualisation of the impact of probabilistic events along with their associated costs over time.

The example above shows the 80/50/20% likelihood of occurrence of whole life costs associated with multiple failure events over the lifetime of transmission and distribution cables in tunnels in different scenarios.

Focus on Electricity Innovation

Electric Power Research Institute : EPRI

Positioning : Strategic
Risk : Range
Benefits : Project Dependent

National Grid Collaboration Advances Electric and Magnetic Fields Science
Understanding and Communicating EMF Science is Critical to National Grid future success

EMF is produced by many sources, including electricity power lines and substations, electrical wiring and equipment. The question of whether EMF associated with the electricity transmission and distribution systems and with residential use affects human health has been studied in depth, and has also been discussed extensively in the media and other public forums. As the demand for electricity capacity and reliability increases, power lines and other electrical equipment are added or upgraded, and companies need to address the EMF issue with regulators, customers, and other stakeholders.

> "EPRI has the only program that addresses the whole breadth of the EMF issue with high-quality, well-managed, research"

As one of the world's largest investor-owned utilities and the largest electricity transmission company in the U.K., National Grid has a robust program of research on the possible association between EMF and human health.

EPRI Membership Enables National Grid to Develop and Communicate EMF Scientific Knowledge

EPRI is one of the only organizations that perform long-term, multidisciplinary EMF research. EPRI's program also includes an external, blue-ribbon scientific advisory committee that provides guidance for the program's research activities. National Grid collaborated with EPRI and another large European utility to cosponsor an international workshop on "EMF Exposure Guidelines Science," which introduced important new concepts to inform exposure guidelines, and also resulted in publication of a special issue of Health Physics, the journal of the Health Physics Society. National Grid recently co-managed a groundbreaking study with the U.K.'s Health Protection Agency to compute the absorption rate of radio-frequency exposures in the near field of an antenna.

John Swanson, one of National Grid's EMF Scientific Advisors, believes its EPRI membership helps National Grid stay connected with its peers and the advancing body of EMF science throughout the world. He notes that if National Grid didn't belong to EPRI, "we wouldn't have the kind of direct access to the global program that EPRI gives us. EPRI is pretty well the only broad EMF research program left in the world today."

In recognition of its strong and ongoing collaboration with EPRI, National Grid is the recipient of an EPRI Technology Transfer Award for its active role in helping to develop and shape the EMF program. The Award also states that National Grid's EMF work aligns directly with its company objectives to take a leadership role on safety and the environment. EPRI Senior Technical Executive Robert Kavet recognizes the value of EPRI's collaboration with National Grid. "It's important for EPRI to have such active members in the program who can bring ideas back to us. They give us an extra layer of oversight." David Renew, an EMF Scientific Advisor with National Grid, summarizes EPRI's and National Grid's collaborative efforts by saying, "The kind of research that EPRI has done and our contribution to it is important. I think it has made a significant difference to the development of the issue and how it's managed in the electricity industry."

Focus on Gas Innovation

Alternatives to venting

Focus : Environmental
TRL : 3 moving through to 7
Benefit : Environmental

TAO/20767 : Alternatives to venting

From time to time there is an operational need for National Grid to depressurise a section of pipeline or part of an above ground facility. For the pipeline, this might be preparation for maintenance work or decommissioning. For a compressor unit, this might be to prevent uncontrolled leakage through the compressor shaft sealing system.

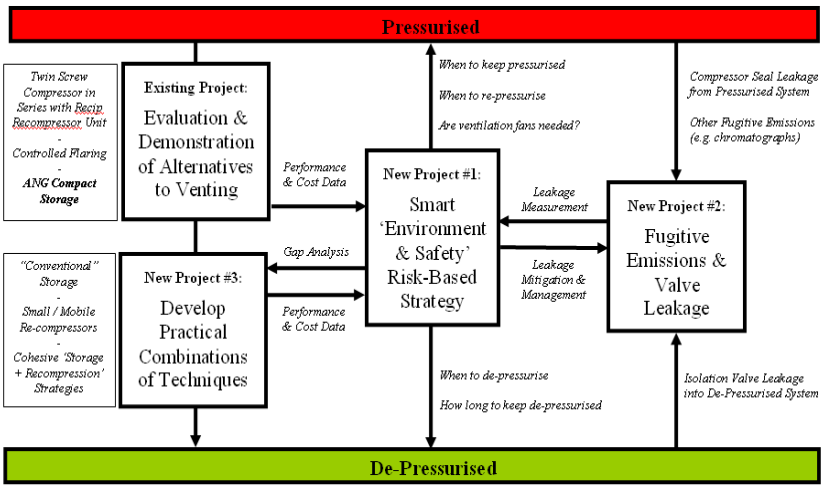
In both cases there is a need to depressurise relatively quickly (to minimise delays to the maintenance project or to minimise seal leakage) the traditional approach to this is to vent Natural Gas to atmosphere. The basic alternatives are to flare, recompress or store the gas. These alternatives were evaluated for various operating scenarios during the initial phase of the IFI project, "Alternatives to Venting of Natural Gas from the NTS". The current phase of the project involves demonstrations of these alternative techniques.

Demonstration 1: Tandem recompression and flaring for pipelines

During preparations for decommissioning work at Bathgate in 2010, a full-scale demonstration was conducted of tandem recompression (one of National Grid's reciprocating units, plus a second hired twin screw compressor in series) and a controlled flaring rig (normally used for safe incineration of hazardous chemicals). Addition of the second recompression rig accelerated depressurisation above the 7barg lower limit (where recompression would normally be suspended) and then took the pressure below 1barg without reaching its limit. The flaring rig was then used successfully for the remaining gas, taking the final pressure below atmospheric pressure.

Demonstration 2: Absorbed Natural Gas (ANG) Storage for compressors

During the initial phase of the project, laboratory-scale tests on a small ANG (volume efficient) storage system provided encouraging results. Analysis also showed that there was potential to install a larger ANG storage system on 5-10 compressor stations, where it would be used to provide the alternative to venting with the least carbon footprint. Work was therefore started on the design of a large-scale demonstration rig. The demonstration rig is being constructed at GLND's flow centre, where detailed evaluation work will not interfere with National Grid operations.



As the project has developed, it has become increasingly apparent that the results of the work need to feed into an overall methane emissions management philosophy. The management philosophy needs to consider fugitive emissions (their quantity compared to venting and whether they are higher when pipework is pressurised or de-pressurised), risk management (safety and environment both need to be considered, currently safety is the initial design criteria does this method exclude alternative solutions.) and the development of practical combinations of techniques that can be brought together for different operational scenarios to minimise emissions of methane to the atmosphere.

Focus on Gas Innovation

Germanischer Lloyd Noble Denton (GLND)

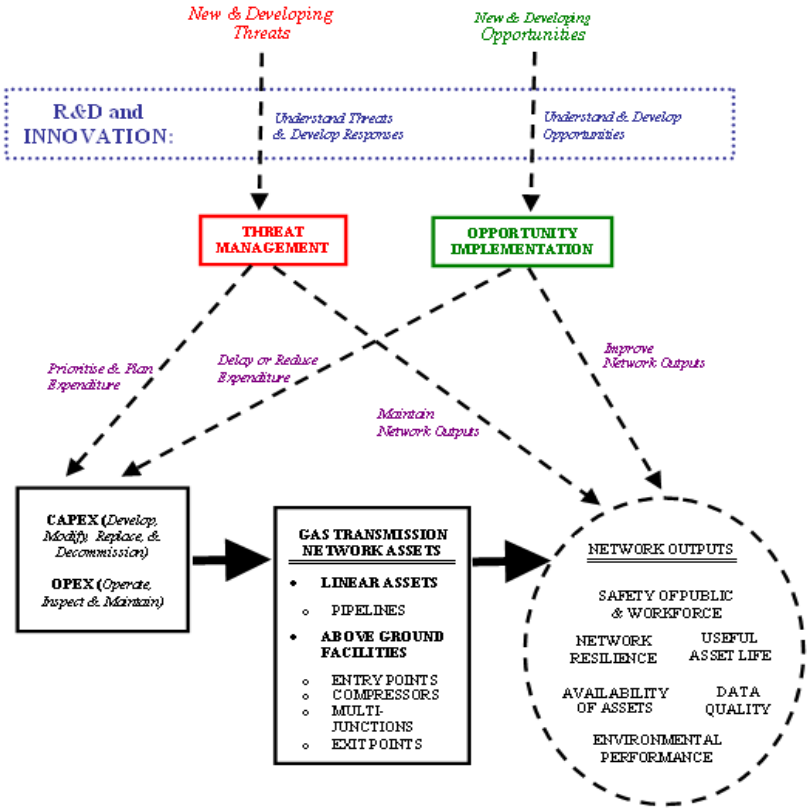
Focus	: Strategic
TRL	: Ranging from 3 to 7
Benefits	: Project Dependent

National Grid have a framework agreement in place with GLND to enable research and development to be agreed and started in an efficient manner. Consequently GLND have a large proportion of the Gas Transmission R&D portfolio which they assist in managing and finding relevant subcontractors.

National Grid Gas Transmission's IFI R&D programme sets out to increase knowledge and introduce innovation addressing the new and developing threats to the performance of the network assets, and new and developing opportunities to improve the performance of the network assets. This is illustrated by the following diagram. The contribution of GLND to this programme is summarised through a number of examples below.

Safety of Workforce and Public

The bulk of work to establish the risk profile of the National Transmission System for natural gas in Great Britain (NTS) was carried out in the 1970s, as the first cross-country pipelines were being planned. However, whilst the basic building blocks of the risk profile have not changed over the years, National Grid still needs to be able to demonstrate that risks continue to be managed to a level which is ALARP (as low as reasonably practicable).



- Third party interference is still the biggest threat to the integrity of pipelines. GLND is therefore developing the technology to improve communication of pipeline locations and associated precautions to the public; GLND have been helping National Grid to evaluate impacts and encroachment detection systems.

- Maximum operating pressures have increased from 70barg up to 94barg in places. GLND has helped National Grid to characterise the pressure cycling behaviour of 94barg pipelines so that the safety risks can be managed effectively.

- New pipeline materials, such as X80, are being used to enable gas to be transported at the highest pressures, while reducing the carbon footprint of construction. GLND has helped National Grid with research into the management of construction defects so that the safety risks can be managed effectively and the management of future welding procedures for diversions and off-takes.

- The composition of natural gas is changing, as continental shelf gas is increasingly being replaced by European gas and LNG imports from around the world. GLND has been helping National Grid research the effects of increased higher hydrocarbons on NTS pipeline assets.

- Parts of the network are 40 years old, meaning that an increasing number of assets are approaching their original design life. GLND has been helping National Grid to improve the understanding of ageing in critical valves and developing a strategy to take some safety block valves out of service and focus new technology

on those that remain. GLND is also evaluating the magneto-tomography over-ground survey method (MTM) to detect and quantify corrosion resulting from coating disbondment in buried pipelines.

- Effective management of corrosion requires new techniques and procedures, particularly in difficult-to-access locations. GLND are helping National Grid to evaluating a number of new inspection technologies, including Hydrotector for detecting corrosion under pipework insulation.

- The increasing use of pipeline corridors by overhead AC electricity lines to connect distributed wind farms could potentially affect the established corrosion mitigation methodology. GLND are developing new techniques for National Grid in conduct surveys and monitor potential AC corrosion hotspots, so that they can be managed appropriately.

- National Grid also continues to invest in its safety risk modelling capability, through research and collaboration with other European and non-European gas transportation companies. GLND manages National Grid's involvement in this and in many cases undertakes the collaborative projects. The output of these projects feeds directly into the improvement of the risk modelling tools used by National Grid for pipelines and above ground installations.

Security of Supply

- The number of excursions from established gas composition standards at the NTS entry points is steadily increasing. GLND is working with IMA UK – Gas and Liquid Analyses and Measurement Systems and ISI Solutions (Intergracion de Sistemas de Informacion) to develop new equipment for National Grid to detect and characterise the more severe incursions, so that decisions to shut down supplies can be supported by best possible information.

- The NTS has a large population of ageing process valves that are used to control the flow of gas through its pipelines and compressors. GLND is helping National Grid improve the understanding of ageing valve condition, so that new in-situ maintenance methods can be developed and, where necessary, replacements can be prioritised.

Environmental Performance

- Emissions of natural gas to the atmosphere are approximately 19 times more damaging to the environment per tonne than carbon dioxide emissions. GLND is helping National Grid to evaluate alternatives to venting that will significantly reduce the natural gas emissions from the NTS.

- The environmental impact of new facilities is a significant concern. GLND has produced a comprehensive series of studies to provide National Grid with an array of environmental options that need to be considered in future environmental "best available technique" (BAT) studies.

Asset Utilisation

- The NTS is faced with significant changes to the importation of gas to the NTS from the Supply side and also subject to changes in the behaviour of customers on the Demand side. National Grid is therefore investing in research to be able to improve the planning of new assets, while optimising the use of existing assets.

- Reutilisations of National Grid pipeline assets are being considered for the transportation of Carbon Dioxide from coal-fired power stations to offshore fields for storage. National Grid is therefore investing in a major research programme to develop the associated safety case. GLND have been heavily involved in this research programme, with CO_2 shock-tube tests and dispersion measurements at its Spadeadam test facility. GLND have also provided support in specialist areas, such as metering and odorisation.

Focus on Gas Innovation

Ageing Valves

Focus : Safety
TRL : 5 leading to policy documents
Benefits : Age profiling assets

IFI projects : TOA/OL600, TAO/OL601, TAO/OL602

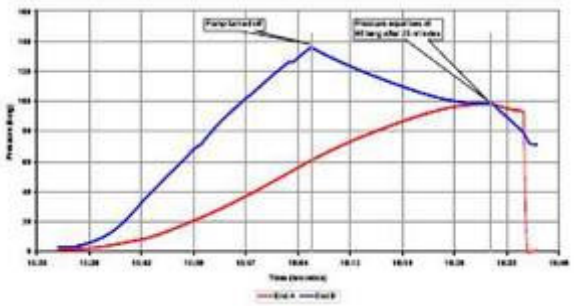
Ageing Critical Valve Assets

This programme of work is looking into the current situation and degradation of the NTS ball valves, as well as seeking to improve efficiency of network operations; therefore minimising the safety risk presented.

Ball Valve Deterioration Testing

The objective of ball valve deterioration testing is to develop an understanding of deterioration mechanisms of in-service transmission ball valves. The project evaluated the condition of two 30" Cort ball valves from Wormington compressor station, both with 17 years of service. One was a station manual isolation valve (low duty cycles; subjected to between 5 & 15 ℃); the other was a unit process discharge isolation valve (high duty cycles; subjected to between 5 & 45 ℃).

The results did not give a clear indication of the degradation rates or mechanisms based upon the age and operating parameters of the valves under test. However, the valve seals on the heavy duty valve exhibited significant leakage, due to scoring of sealing surfaces, probably caused by sand or corrosion product.



As a result of the work, it was recommended that similar deterioration tests be considered whenever Cort ball valves (or other valve types) are removed from service. The results should be compared with the existing results, in order to collate and build a reference of life-limiting degradation factors and failure modes.

National Grid hope to be able to perform valve deterioration tests during next year's programme on two Cameron ball valves that have recently been removed from service.

Ball Valve Sealant Solvent Solubility Testing

Three Nuovo Pignone 42" Ball Valves were removed from Aberdeen Compressor Station due to poor sealing performance. An initial investigation found that the lack of sealant and the inability to inject further sealant were the underlying causes.

A study was undertaken to determine whether old sealant could be removed or softened in situ with the use of a suitable solvent, to allow the injection of new sealant. ECO-SOLV solvent injection was identified as a potential solution.

A series of tests at Pipeline Maintenance Center (PMC) Ambergate on one of the removed valves were used to trial the solvent and gauge its effectiveness. The tests were repeated on an operational valve at Diss Compressor Station. However, in both cases, the results have been inconclusive and inconsistent.

Although ECO-SOLV did soften the existing sealant, it was not completely successful. However a number of lessons were learnt, resulting in recommendations to trial injection pumps with higher flow rates and to consider the development of ECO-SOLV in a gel format.

In the meantime, an opportunity has arisen to evaluate a valve that had been subject to an attempted remediation by means of 'Furmanite' injection into holes drilled about the circumference of the 'Cort' 3-piece bolted closure joint. This

solution has failed over time and the valve was subsequently removed from service. National Grid hope to be able to perform an evaluation of these ball valves during next year's programme.

Plumley Block Valve Removal

An opportunity arose to remove a pit-installed, life-expired block valve from service, due to several 'process safety'-related issues (severe corrosion on small-bore pipework, resulting in natural gas emissions to atmosphere; inability to make repairs in-situ and an inability to operate mainline feeder isolation valve).

Several locally-operated ball valves and associated pipework were also removed to allow further detailed condition analysis on a typical 40year old block valve installation. This would improve the understanding of severity of valve deterioration and failure mechanisms. In particular, the work will provide evidence on the technical asset life of valves that are installed within pits, so that Maintenance Policy can be updated, where appropriate.

The test and analysis work for this project has been completed. Pressure tests on the 36" and 8" valves showed poor sealing capabilities. Further tests were carried out on the main line ball valve stem seal, seat ring seal and spring integrity.

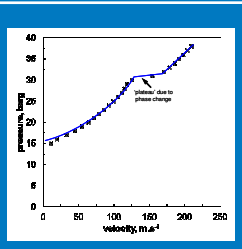
Visual inspections showed no significant external deterioration of the valves or pipe assemblies due to external corrosion. However, non-destructive testing of the welded joints using ultrasonic, magnetic particle inspection and radiography revealed a number of unacceptable weld defects. National Grid are therefore reviewing construction records to identify where the same major works contractor was involved on similar valve construction work, which could then be prioritised for further investigations.

The material properties of the 1", 8", 24" and 36" pipework were determined and further assessments were made on the condition of a number of sub-components, including buried bolted joints and locally operated gearbox internals. The results are currently being evaluated in relation to maintenance policy and the prioritisation of further valve removals.

Focus on Gas Innovation

Carbon Capture and Storage

Focus	: Environmental
TRL	: 4 to 7 over a range of projects
Benefits	: knowledge and understanding



This area of work is key to ensuring the safety of reusing a gas transmission pipeline for the purpose of transportation of Carbon Dioxide

National Grid is considering the change of use of existing natural gas National Transmission System (NTS) transmission pipelines to be capable of transporting anthropogenic Carbon Dioxide (CO_2) from large emitters, such as power stations, to a location where the CO_2 can be safely stored. This will require full demonstration, through preparation of a safety case, that the activity can be carried out safely. Research and development activities are to be undertaken in order that a robust safety justification for the design and operation of gaseous phase CO_2 pipelines can be prepared.

Coal will continue to provide a significant percentage of the electricity generated in the United Kingdom (UK) and around the world as it is reliable, low cost, there are abundant reserves available and coal fired generation can easily respond to fluctuations in energy demand. However, coal is also the fuel with the highest carbon emissions and generates significant quantities of CO_2.

Corrosion test rig

The use of CCS has the potential to reduce CO_2 emissions from fossil fuel power stations by up to 90%.

The Government believes that CCS is an important way of reducing CO_2 emissions given that a significant proportion of the increase in world energy demand is expected to be met by fossil fuels, in particular from coal. CCS can help to meet the UK's increasing energy needs whilst maintaining the security of the energy supply by making coal a more viable option and assists in reducing dependence on gas imports.

CCS is a critical part of the UK's decarbonisation strategy and it facilitates the transition to a low carbon economy.

National Grid's potential involvement in CCS is through offering pipeline transportation services. National Grid has identified the potential for utilising existing NTS pipeline assets that are near to or at the end of their regulatory economic life and that are nearly fully depreciated, for the transport of CO_2.

Photograph of the shock tube test rig

Utilising the existing NTS pipeline assets for CO_2 transportation provides the following benefits:

Photograph of the back end of the test rig

Speeds up the initial deployment of CCS technology whilst reducing costs and minimising risks. This will benefit the UK economy by providing an efficient technical solution to the practical problems posed by CCS.

Helps tackling climate change by allowing faster testing of the feasibility of CCS as a means of substantially abating carbon emissions.

Provides an opportunity for gas consumers to extract residual value from the pipelines being reused which are otherwise expected to be relatively under utilised in the medium term.

The R&D work undertaken provides a good foundation for the facilitation of CCS implementation and supports the Government's objectives.

National Grid can now define pipeline operating conditions to ensure pipeline operation is always in the gaseous phase and have a validated method for setting toughness levels to ensure crack arrest in pipelines operating with gaseous phase CO_2 and mixtures based on the detailed shock tube test programme conducted. Reuse of existing pipeline assets minimises the costs of capital investment, the impact on the environment and defers/offsets decommissioning costs for existing pipeline assets which have come to the end of their regulatory economic life.

Photograph of the front end of the test rig

Finance Overview and Benefits of Programme

This section of the report gives the financial information associated with the 2010/11 programme as agreed in the Innovation Good Practice Guide for Energy Networks (G85).

In year 4 there where 122 live projects moving through the research, development and demonstration phase with the total spend of £8.97m utilising 99.4% of the IFI allowance. R&D outputs form an integral part of National Grid's asset management activities they are integral for finding solutions to technical problems and managing risk.

Benefits are assessed on an individual basis and reported on in the detailed section of the report; the IFI portfolio is delivering a balanced programme of work providing an overall positive NPV. Benefits taken into consideration are:

- Safety
- Environmental
- Network Performance
- External risk

While NPV and Knowledge transfer are also taken into consideration when assessing the benefit of the project. Benefits from the programme are achieved in the form of:

Direct costs– e.g. through reduced planned capital expenditure or refurbishment.
Avoided costs- e.g. through deferred investment, reduced failures, establishing true condition of equipment potentially improved ratings.

The overall Net Present Value (NPV) for the current Electricity Transmission portfolio is £16 m. The overall NPV for the current Gas Transmission portfolio is valued at £11m.

IFI sponsored research has been a major contributor in allowing NGG to identify where there are sections of NTS pipeline that are redundant then they can be converted to use carrying gaseous phase CO_2. Subsequently NGG has identified that a feeder in Scotland can be sold for CO_2 transportation as part of one of the government's CCS demonstration projects. If approved by The Authority this will realise around £30m (to be shared between NGG and customers) in respect of an asset that was about to become redundant and with a book value of some £0.4m

The IFI programme also delivers a range of non financial benefits such in safety and environment, while these produce negative NPV's they are still key to providing benefit to National Grid and its customers.

Electrcity IFI

IFI Allowance	**£6.164m**
IFI Carry over	**£0**
Number of Active Projects	**93**
External Expenditure	**£5.358m**
Internal Expenditure	**£0.788m**
Total Expenditure	**£6.146m**
Anticipated IFI Allowance (For 2011/12)	**£6.583m**

Gas IFI

IFI Allowance	**£2.722m**
IFI Carry over	**£0**
Number of Active Projects	**29**
External Expenditure	**£2.462m**
Internal Expenditure	**£0.233m**
Total Expenditure	**£2.695m**
Anticipated IFI Allowance (For 2011/12)	**£2.849m**

Looking Forward

Our Innovation Strategy has been reviewed during 2011 to ensure it maintains its relevance through the transition to the new innovation allowance as part of the RIIO consultation, while ensuring that the innovation strategy remains aligned to National Grid's line of sight. National Grid has been a keen contributor to Ofgem's Innovation Working Group and will continue to engage over the upcoming years.

Our aim is maximise the benefits from the current portfolio during the remaining price control period. As well as initiating initial studies that could potentially lead into the development of larger project to take forward under RIIO.

We expect to utilise the full IFI allowance in 2011/12 on planned existing and new work proposals.

Governments estimated that £200Bn will need to be invested in the UK's energy sector over the next ten years, including ~£30Bn in networks to replace ageing assets and connecting new sources of energy. To deliver this to time offering value for money for the end consumer we need to be innovative in the way we deliver these projects.

Embedding a culture of innovation is pivotal in delivering the outputs required by our stakeholders. Innovation needs to drive learning in the networks businesses - deliver value to consumers, such as reducing cost of delivery, improved efficiency, reduced environmental impact, improved safety or reduced time to deliver.

We are in a unique position to safeguard the environment for future generations through the infrastructure that we provide and services we deliver to support a lower carbon future. Innovation is a key driver to embed more sustainable approaches minimizing our environmental impacts.

As we progress through this decade, we will need to invest significantly in assets and technology, innovation will be key to establishing the efficient, effective, economic and sustainable solutions to the upcoming challenges for example overcoming the barriers (both cost and technology) to HVDC connections.

Effectively we need to convert our transmission assets into a more flexible system, which will facilitate delivery of governments UK carbon targets and insure the safety of the environment for future generations.

> "We cannot under-estimate the scale of the engineering challenge that will be needed to deliver a sustainable energy future. One which I believe is going to lead to a renaissance in engineering. As we embark on this transformation, we are going to need new technologies, new players, and new engineering talent"
>
> Steve Holiday CEO National Grid

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