Gas Network Innovation Competition
Screening Submission Pro-forma

Funding Licensee
National Grid Gas Distribution
Network Licence Project Partners
Severn Trent Water Limited, Hydrogenics B.V., Electrochaea GmbH, CNG Services Ltd.
Funding Licensee area
National Grid Gas Distribution – East Midlands
Project title
Power-to-Gas for Large-Scale Energy Storage Applications Project ("P2G-LEAP")
Project Summary
The P2G-LEAP ("Project") aims to provide a solution to maximise the use of renewables by using the gas network as an energy storage infrastructure. This project will take the power-to-gas (P2G) technology concept to market readiness for the sustainable production of biomethane and the efficient integration of intermittent renewables, such as wind and solar. This objective is attained through the engineering, design, construction and operation of a 5-MW power-to-gas facility using state-of-the-art technology components integrated into an existing sewage treatment works. Once operational, the facility will produce biomethane for direct injection into the local distribution network. In addition, it will produce heat and oxygen for the local wastewater works and could provide grid stabilization services to the electricity grid. In so doing, the P2G-LEAP facility will demonstrate how P2G can make a substantial contribution to achieving the UK Government's greenhouse gas reduction objective as stated in the Carbon Plan. The P2G-LEAP demonstration facility will be built and operated at the Derby sewage treatment works of Severn Trent Water. Hydrogenics and Electrochaea will deliver the electrolyser and methanation unit, respectively, while CNG Services will provide engineering and project management services. The Project's budget is anticipated to be of the order of £16 million and is expected to run for three years, starting in Q1-2016 and concluding in Q4-2018.

Estimated Project funding			
Total cost of Project	£16 million	**NIC funding requested**	£4.8m (30%)
Cross Sector Projects only: Requested funding from Electricity NIC or NIA?	N/A		

Problem(s)

In its landmark publication *The Carbon Plan – Delivering Our Low Carbon Future,* the UK Government has formulated a long-term plan for cutting greenhouse gas emissions by 80% by the year 2050 (HM Government 2011). Central to achieving this ambitious target is a very significant increase of renewable energy capacity to 30-40% of total generation capacity by 2020 and 50% by 2030 (National Grid 2011, Redpoint 2009, DECC 2010).

The fluctuating nature of wind (and solar) energy poses an enormous challenge to the UK energy system: wind and solar plants produce electricity intermittently and independently of demand, yet supply and demand in the electricity system need to be balanced at all times. As yet, no economic, large-scale seasonal, or even diurnal, electricity storage technology is available (apart from pumped hydro storage at a few favoured locations). As a result, the UK electricity system is likely to experience more frequent and prolonged periods of excess power supply, leading to very low and even negative power prices as well as curtailment of electricity production: it is estimated that up to 58 TWh (approx. 15% of annual electricity demand) of wind power will be curtailed each year once wind penetration has reached 55% (Imperial College 2012), a direct loss caused by the underutilization of expensive assets.

The integration of intermittent renewables is not the only problem that needs to be solved in the transition to a low carbon economy, as is acknowledged by the Carbon Plan. The gas sector is facing its own challenges:

- Domestic natural gas resources are declining, while natural gas demand is expected to remain stable or even increase in the decades ahead (E4Tech 2013).
- Decarbonising the heating sector has been called "one of the most significant challenges in the transition to a low carbon economy (The Energy Research Partnership 2011, p. 6)."
- A significant proportion of gas customers, most notably the commercial and industrial sector, will be unable to switch from gas to electricity and continue to rely on methane as an energy carrier of choice.
- Fast-ramping combined-cycle gas turbines will continue to be required to provide balancing services to the power grid and will rely on a source of renewable fuel.

By providing an additional source of renewable gas, P2G can complement other sources of biomethane such as AD and gasification and help address these issues without modifications to the existing gas distribution and utilization infrastructure. In so doing, it would contribute to the UK Government's key objectives of increasing energy independence and security of supply.

Method(s)

Power-to-gas (P2G) is a two-step process for the conversion of renewable electricity to renewable gas. In the first step, electricity is converted to hydrogen and oxygen by electrolysis of water. In the second step, the hydrogen is combined with carbon dioxide and catalytically reacted to methane. The resulting product gas can be conditioned to meet the quality requirements of the UK gas network so that it can be injected into existing pipelines (analogous to biomethane). The by-products heat and oxygen can be recycled in industrial processes, and the electrolyser can provide grid balancing services to the electricity network.

Method(s) - continued

P2G thus utilizes the existing storage capacity of the gas network to store large amounts of renewable electrical energy. It creates a bi-directional link between the electricity and gas sectors and therefore allows the efficient management of energy resources at each point in time.

Once in the grid, the renewable gas from P2G can be used for power production in gas turbines and as a low carbon energy source for domestic and industrial customers to help meet their heating needs. It can also be used as a fuel in the transportation sector, especially in mobility applications that are difficult to electrify (e.g. heavy goods and public service vehicles).

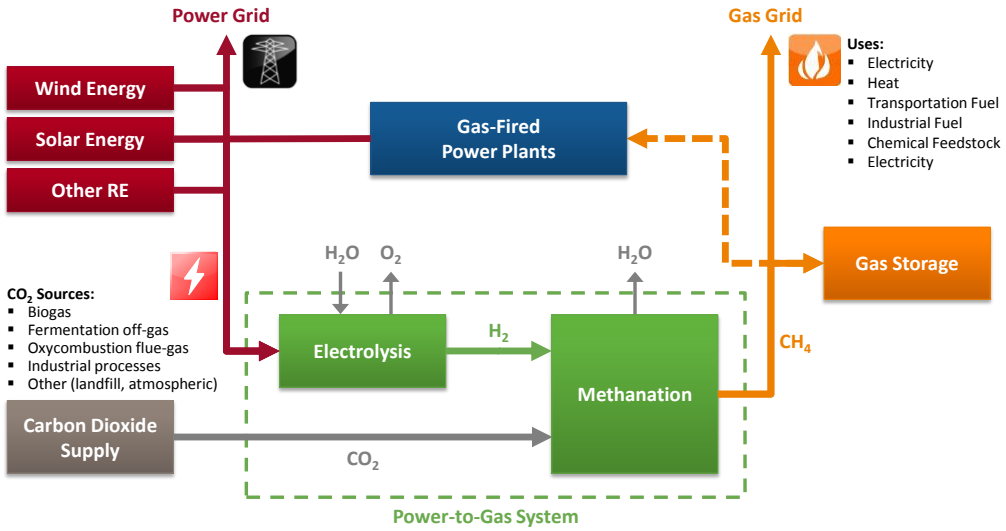


Figure 1: power-to-gas system schematic

There are two distinct features that make P2G particularly well suited for the UK energy system:

- The vast storage capacity of the gas network allows P2G to provide seasonal energy storage. In the UK, the domestic wind resource is twice as high in the winter (Jan/Feb) than in the summer (Jul/Aug)(Sinden 2007). Shifting some of that resource from the winter to the summer via P2G energy storage can contribute to lowering the peak capacity requirements for the entire electricity system.
- The UK's wind resource is most abundant in the north, at large distances from the high-demand centres in the south. Building additional electricity transmission capacity is costly and likely to face severe public resistance, as is the case in other countries (most notably Germany). Through P2G, the existing gas transmission network can be used to transport energy from the north to the south without modifications or extensions.

The technical potential of P2G in the UK is linked to the availability of CO_2, especially from biogas. It is estimated that up to 18% of total UK gas demand (~97 bcm) could be met by biomethane (National Grid 2009). P2G could increase the output of such biomethane facilities by up to 40%, adding 39 bcm or 7% of total gas demand from biogas alone. As other CO_2 sources are plentiful, the total technical potential for P2G in the UK is much higher.

Method(s) - continued

In sum, power-to-gas can:

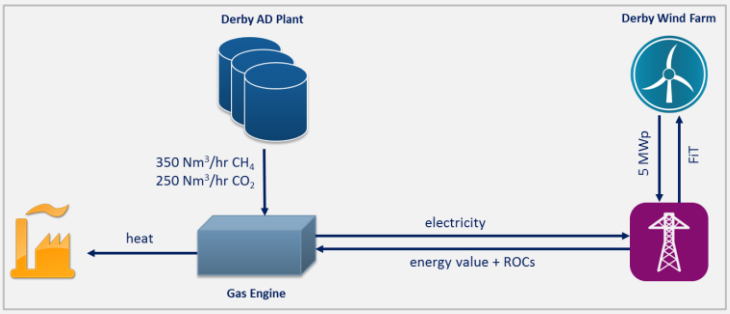
- Increase the share of renewable gas in the UK's gas network to help decarbonize the gas, heating, and transportation sectors;
- Contribute to the reduction of curtailment of wind and solar power plants;
- Increase the efficiency with which the UK manages its energy sectors by providing seasonal storage and geographic energy transmission enabled by the gas network;
- Contribute to balancing the power grid through ancillary services provided by the electrolyser;
- Increase domestic gas production and contribute to security of supply and energy independence.

The Project would, for the first time, bring large-scale power-to-gas to the UK. By building the UK's first fully-fledged P2G plant and the world's largest facility based on PEM electrolysis and biological methanation, the P2G-LEAP project would pioneer a new technology concept that could point the way for countries around the world to integrate large fractions of renewable energy into their energy systems.

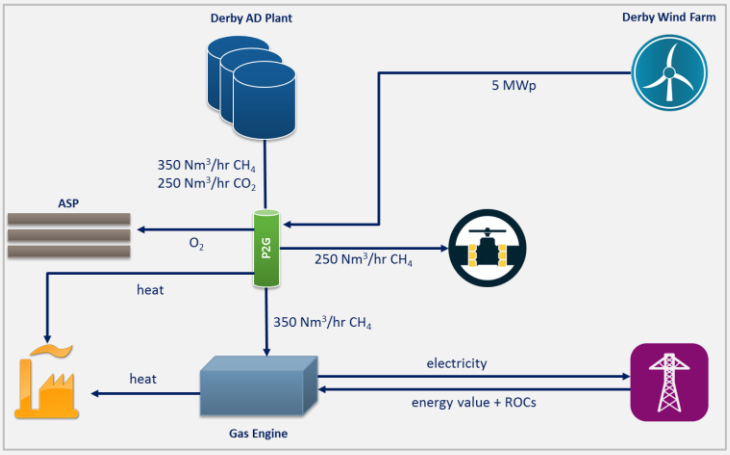
Operating Modes of P2G Plant at Derby Sewage Plant

Under the P2G operating mode, 250 Nm^3/hr of CO_2 will be converted to methane (using locally produced wind energy) and exported to the local gas distribution network. Oxygen and heat will be recycled on site. The on-site CHP unit will continue to receive the same amount of methane for the production of electricity and heat to satisfy the energy consumption of the sewage works.

<u>Operating Mode 1:</u>
Business as Usual



<u>Operating Mode 2:</u>
Power-to-Gas
(during times of low electricity prices)



Accelerates the development of a low carbon energy sector & has the potential to deliver net financial benefits to existing and/or future Customers

Contribution to Carbon Plan & Delivery of Environmental Benefits to Customers

There are multiple ways in which P2G contributes to the achievement of the Government's objectives described in the *Carbon Plan,* mainly to the key objective of reducing greenhouse gas emissions by 80% compared to 1990 levels by the year 2050.

The main contribution stems from the injection of renewable gas into the gas network, making available a low carbon energy carrier to the heating, transport, and power generation sectors:

- Decarbonising the **heating** sector has been found to be a major challenge. The Carbon Plan estimates that 21-45% of the heat supply to UK buildings needs to be low carbon by 2030 (p. 5). Renewable gas from P2G has a low carbon footprint and can be readily deployed using the existing gas delivery and utilization infrastructure, including domestic boilers. In fact, a study has shown that using low carbon gas from P2G in conjunction with existing gas boilers could be a cheaper alternative to decarbonise domestic heating than installing millions of ground-source heat pumps, as is advocated in the Carbon Plan (E4Tech 2013).
- In the **transportation** sector, emissions from the average new car will need to fall to between 50g and 70g CO_2/km, from 144g CO_2/km in 2010 (p. 5). A CNG vehicle fuelled with renewable gas from wind energy has a total lifecycle carbon footprint of 53 gCO_2/km – including embedded emissions in manufacturing the vehicle (AUDI 2015). P2G could therefore make a substantial contribution to decarbonising vehicles that cannot be electrified.
- The Carbon Plan also states that the UK energy system will continue to rely on new **gas-fired power plants** to provide the fast-ramping power generation capacity required to balance the UK electricity grid. P2G provides these power plants with a low-carbon fuel.

It is also noteworthy that renewable gas from P2G avoids the concerns described in the Carbon Plan around the sustainable sourcing of biomass used for biofuels production, especially at scale (p. 18). The principal substrates of P2G are carbon dioxide – a waste product readily available – and hydrogen, which is produced from electrolytic water splitting. P2G therefore allows the expansion of the renewable gas production base without additional biomass feedstock.

Other goals stated in the Carbon Plan are supported directly or indirectly through the operation of a P2G facility. First, the electrolyser used in P2G-LEAP is flexible enough to provide balancing services to the power grid, making it "stronger and smarter to reflect the quantity, geography and intermittency of power generation (p. 16)." And second, the by-products heat and oxygen can be recycled in the existing wastewater treatment operations, reducing the carbon footprint of such facilities. At suitable locations where it is possible to develop district heating grids, the heat could also be injected into these. District heating grids are referred to in the Carbon Plan as a major focus of the Government in the heating sector (p. 6).

Accelerates the development of a low carbon energy sector & has the potential to deliver net financial benefits to existing and/or future Customers (continued)

Power-to-gas is uniquely positioned to contribute to a range of objectives declared in the Carbon Plan. By supporting the Project, Ofgem has an opportunity to support the development of this option now so that the "UK will not only reduce the costs of deploying these technologies in the 2020s [but] also gain a long-term competitive advantage […] (p. 5)." A number of European countries have already hosted P2G demonstration projects (albeit none of the type and scale proposed for P2G-LEAP) and gained valuable information about the performance of such systems and the benefits for their domestic energy system. The successful execution of a large-scale P2G project in the UK would enable industry stakeholders to gain valuable experience with the P2G technology concept and to refine their understanding of the value proposition today and in the future.

Expected Financial Benefit to Customers

P2G-LEAP has a strong focus on minimizing the capital and operating costs of a commercial-scale P2G plant. If the Project is technically and economically succesful, Customers will gain access to a low carbon gas at potentially lower cost than that of competing technologies. Further, as gas customers are also electricity customers, they will leverage their financial contributions already made to support the deployment of renewables by enabling the efficient integration of wind and solar energy through P2G. Longer term, P2G is expected to enable the transition to a low carbon economy at a lower cost than alternative solutions (e.g. Fraunhofer ISE 2015, PHOTON 2012).

Delivers value for money for gas Customers

Potential Impact

The Project will produce gas that meets the GSMR specification, and will therefore have no adverse impact on the network. The network will benefit from a new secure source of renewable gas.

Justification of the Scale/Cost of the Project in Relation to Learning

Across Europe, there have already been a significant number of P2G R&D projects, each with a specific – but narrow – topical focus. While these projects have created a broad knowledge base, most of them have not been carried out at commercial scale. Yet issues of scale-up, plant integration, operability, and maintainability can only be studied through a real-world, commercial-size demonstration project.

The selected size of 5 MW_e (electrical input at the electrolyser) represents a five-fold scale-up over the current state-of-the-art for PEM electrolysis and biological methanation and will allow the technology to reach market readiness. Further, 5-MW_e is equivalent to the power generation capacity of the two wind turbines located on the premises of the Derby sewage treatment works, allowing the LEAP facility to be closely (and realistically) integrated into the sewage plant.

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Delivers value for money for gas Customers (continued)

Competitive Cost

P2G is one of several technological solutions proposed for the decarbonisation of the gas network and the integration of intermittent renewables. Therefore, the P2G technology concept must not only demonstrate technical capability but also economic competitiveness in order for market uptake to occur. The key technology partners in the Project, Hydrogenics and Electrochaea, have a strong self-interest in executing the project at the lowest possible cost in order to demonstrate to the energy market the economic performance of their technology. Cost minimization is a key objective pursued throughout the Project. The efforts undertaken toward achieving this objective will be supported by rigorous, state-of-the-art project controlling and auditing.

Proportion of Benefits Accruing to Gas Transportation System

The gas transportation system benefits from P2G by transporting more renewable gas, thus securing the long-term future for the gas network in a low-carbon environment. The transportation system also benefits from adopting a new role in the future UK energy system: as a storage infrastructure for intermittent electricity, it can provide important buffer capacity for the more efficient integration of intermittent renewables.

Funding commentary

The Licensee must provide a commentary on the accuracy of its funding estimate. If the Project has phases, the Licensee should identify the approximate cost of each phase. IGTs should indicate potential bid costs expenses.

The actual costs of delivering such a large and complex project are influenced by several factors which are well known but difficult to forecast without rigorous analysis. The partners in the Project have extensive experience in executing commercial-scale demonstration projects and will conduct a rigorous budget analysis, including thorough pre-engineering assessments, as part of the preparation phase for the Full Submission. The budget will be presented with a detailed break-down by cost category (labour, materials, etc.) and project phase (engineering, construction, operations, etc.). Based on previous demonstration projects and commonly used scaling factors, the costs for the Project are anticipated to be of the order of £16 million, including contingencies.

Specific Requirements (please tick which of the specific requirements this project fulfils)

A specific piece of new (ie unproven in GB) equipment (including control and/or communications systems and/or software)	X
A specific novel arrangement or application of existing gas transmission or/and distribution equipment (including control and communications systems software)	
A specific novel operational practice directly related to the operation of the gas transportation system	
A specific novel commercial arrangement	

Demonstrates the Project generates knowledge that can be shared amongst all Licensees

1) New Knowledge

P2G-LEAP will augment the technology readiness level of P2G. Consequently, it will generate a wealth of knowledge about the design and operation of such systems and their value to the UK energy system. The key learnings are expected to occur in the following areas (non-exhaustive):

- Engineering Knowledge
  - Optimal integration of PEM electrolyser with biological methanation
  - 5x scale-up of PEM electrolyser and biological methanator
  - Optimal integration of P2G with existing sewage works to optimize local energy production and consumption and maximize P2G by-product use (heat + O_2)
  - Process control knowledge in context of integration with wastewater works
- Operating Knowledge
  - Real-time data about product gas composition under intermittent hydrogen flow
  - Data about efficiency/responsiveness/productivity/robustness/longevity of system
  - Data about operability, reliability, and maintainability of system
- Regulatory Knowledge
  - Understanding of permitting requirements of P2G in the UK
  - Eligibility criteria for electrolyser to provide of grid balancing to UK power grid
- Economic Knowledge
  - Data about capital, operating, and maintenance costs, and quantification of ROI
  - Development of a value-maximizing trading strategy in the UK market
  - Refinement of unit economics to study deployment of P2G in the UK

2) Knowledge Capture & Dissemination Methodology

The P2G-LEAP consortium believes that generating intellectual property is a critical component of building a successful energy storage business, and intellectual and financial resources will be committed to capture new IP as the opportunities arise. The Consortium's principals have extensive experience as inventors, as IP portfolio managers, and with IP driven transactions.

New knowledge created in the Project will be shared with industry stakeholders through a well-defined dissemination plan that includes reports, a project website, speaking engagements at conferences and trade shows, and articles published in industry magazines, among others. The consortium will also host visitors on site and offer tours and workshops for interested industry stakeholders and the wider public.

Please tick if the project conforms to the default IPR arrangements set out in the NIC Governance Document?	X

The Consortium recognizes that one of the key objectives of the NIC is to transfer knowledge gained in the project in order to enable Network Licensees to deploy the Methods tested in NIC projects. All parties in the P2G-LEAP project are therefore strongly committed to enable the roll-out of the P2G technology in the United Kingdom by engaging in knowledge transfer and information dissemination activities.

Due to the particular funding strategy for the P2G-LEAP project, which is based on a 70%/30% split between Horizon 2020 and NIC (see "External Funding" below), there will be a need to harmonize certain legal aspects of how the project is governed, including with regards to IPR. The design of a mutually acceptable IPR arrangement that meets the requirements of the Network Innovation Competition and the European Commission requires the engagement of legal counsel. Due to the costs involved in such an activity, the consortium would like to defer this action to the preparation phase for the full submission.

We currently expect this harmonization effort to have no material impact on the default IPR arrangements defined for project participants.

How is the project innovative and with an unproven business case where the innovation risk warrants a limited Development or Demonstration Project to demonstrate its effectiveness.

Innovation risk in the P2G-LEAP project is present on two different levels:

1. **Technological:** The two core components of the P2G-LEAP facility – PEM electrolysis and biological methanation – have never been demonstrated as a tandem at multi-MW scale. The scale up and integration of these components will lead to the considerable generation of technical knowledge, including new IP, and lift the P2G concept to TRL7.
2. **Economic:** The business case for P2G depends primarily on two factors: capital cost and net cash flows generated during operations. Capital costs for a technology at TRL6 are extremely difficult to estimate unless a scale-up is performed in the real world, which is the major objective of the Project. Similarly, the net financial benefit of operations can only be determined with real-world data on energy conversion efficiencies, by-product recovery rates, and electrolyser response rates (relevant for grid balancing services).

It is to be expected that funders would be unwilling to accept the risk associated with a first of a kind plant and will require a demonstration that the technology can be operated commercially before proceeding with developments.

Further, there are no routes for National Grid to commercially benefit from the development of this technology, so National Grid would not invest in this Project in its normal course of business.

Project Partners and external resourcing/funding

Project Partners: P2G-LEAP is undertaken by a consortium of highly qualified organizations which are leaders in their respective fields. With their combined expertise, they maximize the probability of the Project being executed safely and on time and within budget. In addition to **National Grid Gas Distribution,** the following organizations will participate in P2G-LEAP:

- **Severn Trent Water:** STW are one of the largest operators of sewage treatment works in the UK and pioneers in deploying renewable energy technologies. STW will contribute valuable engineering support to facilitate the integration of the P2G plant into the sewage works and operate the facility during the demonstration phase. The company's key interest in P2G lies in the technology's potential to optimize the production and consumption of renewable energy at their other sewage works, including 36 that already produce renewable energy.
- **Hydrogenics Europe:** Hydrogenics have been developing water electrolysers for over 60 years and have installed over 1'000 systems worldwide for many different applications. The company has also been proactive in pushing renewable solutions forward by being part of the European Commission's industry grouping FCH JTI (Fuel Cells and Hydrogen Joint Technology Initiative) and by delivering equipment to many renewable projects, including for power-to-gas applications. The company's latest product is a 1 MW PEM electrolyser, which for the first time will be deployed at multi-MW scale in the Project.
- **Electrochaea GmbH:** A spin-off from the University of Chicago, Electrochaea is one of the leading technology developers in the field of biological methanation. The company is currently testing its technology at a scale of 1 MW at a sewage treatment works in Copenhagen, Denmark, a project sponsored by the Danish TSO Energinet.dk. The learnings from this demonstration will form the knowledge base for the scale-up and integration work performed in P2G-LEAP. Electrochaea will provide its biological methanation technology to the P2G-LEAP project and act as the overall project manager.
- **CNG Services:** CNG Services is the leading engineering consultancy for biogas-to-grid projects. The company provides design, consultancy and project management services in relation to upgrading of biogas, injection of biomethane into the UK gas grid, design and project management for gas pipelines, development of onshore UK gas reserves and gas storage, and use of CNG as vehicle fuel. The company's professionals will provide engineering and project management services to P2G-LEAP.

External Funding

The P2G-LEAP consortium will submit a funding application to the European Commission's Horizon 2020 funding program (funding call LCE9 for large-scale energy storage; submission deadline 5 May 2015, notification by autumn 2015). If successful, H2020 will fund 70% of the total project cost. The funding sought from the NIC is intended to cover the remaining 30%. The Horizon 2020 grant provides the opportunity to greatly increase the value for money available from the NIC funding.

Derogations or exemptions

None.

Customer impact

No customer impact is anticipated to result from the Project. Renewable gas from P2G will meet the gas quality requirements of the UK gas network and hence be interchangeable with natural gas.

Details of cross sector aspects

N/A

Any further details the Licensee feels would add to the submission
References referred to in the text: ▪ AUDI AG. "Audi e-fuels: The Audi e-gas Project." 2015. ▪ DECC. "2050 Pathways Analysis." 2010. ▪ E4Tech, "Support to DECC Competition – Contribution to Phase 1 Report, Final Draft." 2013. ▪ Fraunhofer ISE. "The Role of Power-to-Gas in Achieving Germany's Climate Policy Targets with a Special Focus on Concepts for Road Based Mobility." Freiburg, 2015. ▪ Imperial College. "Understanding the Balancing Challenge." Report for the Department of Energy and Climate Change (DECC), London, 2012. ▪ National Grid. "The Potential for Renewable Gas in the UK." Warwick, 2009. ▪ National Grid. "UK Future Energy Scenarios." 2011. ▪ PHOTON. „Herr Altmaier, so geht's!" PHOTON – Das Solarstrom-Magazin, 2012. ▪ Redpoint. "Decarbonising the GB power sector: evaluating investment pathways, generation patterns and emissions through to 2030. A report to the Committee on Climate Change." 2009. ▪ Sinden, Graham. "Characteristics of the UK wind resource: long-term patterns and relationship to electricity demand." *Energy Policy*, 2007. ▪ The Energy Research Partneship. "The future role for energy storage in the UK: Main Report." 2011.
Contact name
David Pickering
Contact Address
National Grid Gas Distribution Network Strategy Hinckley Operation Centre Brick Kiln Street, Hinckley LE10 0NA
E-mail
david.c.pickering@nationalgrid.com
Direct telephone line
07867 537360
Job title
NIC Project Manager