SUSTAINABLE GAS FUTURES: Science Plan

SUMMARY

A partnership is proposed between FAPESP Sao Paulo Research Foundation, Brazil and the UK's Natural Environment Research Council (NERC) to establish a joint science-led research programme, of an internationally excellent standard, into ***Sustainable Gas Futures.*** The main aim of this research programme is to help to find sustainable forms of power (heat, lighting) to ensure a secure energy supply is available to meet the demands of the population of Brazil.

The high level goals of the programme are to: 1) develop new methodologies to characterise, explore, analyse and assess the role of gas in current and future energy systems, considering both economic and environmental sustainability indicators; 2) deliver alternative views of the future of gas in low carbon energy systems, and to identify key sustainable technologies within those futures; 3) engage with current and possible future technology options throughout the gas value chain and across competing and synergistic energy vectors and technologies, to ensure that the analysis is grounded in engineering options in particular the synergies and differences between the UK and Brazil in gas; 4) capacity building through a whole systems energy approach to address Ecosystem Services[1] across energy technologies associated with the development of a sustainable gas future and 5) develop common learning and understanding of the future of gas in both countries and worldwide supported by the Newton Fund, with a focus on research contributing to the economic development and welfare of Brazil as part of the Sustainable Gas Futures programme.

This programme of joint research between the UK and Brazil will help promote the long-term economic, social and environmentally sustainable growth for Brazil's future energy system. The research will draw upon knowledge in both countries to ensure delivery of a low carbon energy system and sustainable technologies to enable Brazil to meet its environmental and welfare commitments.

The programme will address three of the eight themes identified at the scoping workshop:

1. ***Gas and Environmental Sustainability***
2. ***Novel Gas Processing***
3. ***Innovative Technologies for Natural Gas Production***
4. ***Infrastructure***
5. ***Carbon Capture and Storage***
6. ***Assessment and Evaluation***
7. ***Bioenergy and Gas***
8. ***Social License***

The focus of the programme will be capacity building through a whole systems [2] approach to energy research by examining the social, environmental (including Ecosystem Services[3]) and economic impacts of energy pathways and choices, as well as the challenges across energy technologies associated with the development of a sustainable gas future in Brazil.

The programme will be funded up to £1 million in total, with matched equivalent effort from FAPESP to support a consortia research project, spanning three years that will address three of the eight identified research themes. This will include Knowledge Exchange activities within the programme costs to facilitate linking of the research themes, the communication and application of the science delivered from this

[2] http://www.rcuk.ac.uk/research/xrcprogrammes/energy/EnergyResearch/whole/

[3] See for example the UK National Ecosystem Assessment (UK NEA): http://uknea.unep-wcmc.org/EcosystemAssessmentConcepts/EcosystemServices/tabid/103/Default.aspx

programme, capacity building, education, scientific exchange and informing policy, in order to increase the skills and knowledge base at the partners' institutions in Brazil.

1. RATIONALE

In the area of energy, Brazil forecasts a 60% growth in the domestic energy demand in the next decade. Currently Brazil has a clean matrix, with 46% of its energy from renewables (mainly relying in large on hydropower and biofuels) and has committed to maintain its percentage of low carbon energy in the matrix.

However, to meet society's increasing demand for energy, at the same time as safeguarding the welfare of its people and ensuring Brazil meets its commitment target, the country will need to increase its economic investment in new renewable energy and other low carbon technologies. This research programme will help to find sustainable forms of power (heat, lighting) to ensure a secure supply is available to meet the demands of the whole population of Brazil.

This programme of joint research between the UK and Brazil will help promote the long-term economic, social and environmentally sustainable growth for Brazil's future secure energy system. This will be achieved by developing new methodologies to characterise, explore and analyse the role of gas as part of Brazil's future energy options. The programme will explore current and possible future technology options to ensure that the analysis is grounded in engineering options viable to Brazil, particularly to expand their growing industry.

The programme has developed as a result of the synergies and differences between the UK and Brazil in gas. The UK once had a major resource and now is a major user in power, buildings and industry; it has a mature and extensive gas infrastructure; and the potential for capacity building in Brazil in alternative technologies, such as CCS and shale gas to come on stream. Comparatively Brazil has relatively untapped major gas resources; has limited gas infrastructure; and very different demand and natural resource characteristics.

The research will draw upon knowledge in both countries to deliver alternative views of the future of gas in low carbon energy systems, and to identify key sustainable technologies within those futures to enable Brazil to meet its environmental and welfare commitments. Through this research and development Brazil will build capacity and thereby drive economic development. As new high-tech gas industries are being explored through this programme it will provide an opportunity to train, develop and provide potential exportable skills for the Brazilian people allowing for greater employment opportunities for the population.

The whole systems[4] approach is required to examine the social, environmental (including Ecosystem Services[5]) and economic impacts of energy pathways and choices, as well as the challenges across energy technologies associated with the development of a sustainable gas future in Brazil.

The following definition has been suggested for a whole systems approach: 'whole-systems energy research aims at a better understanding of the energy landscape, incorporating socio-economic, physical, natural, environmental and biological systems, at all spatial and temporal scales. It addresses complexities, interactions and interdependencies within the landscape, and other systems. Whole-systems energy research necessarily draws upon a wide range of disciplines and methodologies, but it does not demand comprehensive coverage at the level of individual projects.

This is a UK strength and as such this initiative will strengthen partnerships between UK and Brazilian researchers in this field. It is vital, and recognized by Brazil, that the rapid development of gas resources must be carried out sustainably using environmental science to take a whole energy systems approach and that sustainable technologies are an integral part of this approach.

The Sustainable Gas Futures programme will pay particular attention to improving science and innovation expertise ('capacity building') and implementing a research and development collaboration to enable sustainable and environmentally acceptable economic growth in Brazil.

2. GOALS

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[4] http://www.rcuk.ac.uk/research/xrcprogrammes/energy/EnergyResearch/whole/

[5] See for example the UK National Ecosystem Assessment (UK NEA): http://uknea.unep-wcmc.org/EcosystemAssessmentConcepts/EcosystemServices/tabid/103/Default.aspx

The goals of the Sustainable Gas Futures programme are to:

1) Develop new methodologies to characterise, explore, analyse and assess the role of gas in current and future energy systems, considering both economic and environmental sustainability indicators.
2) Deliver alternative views of the future of gas in low carbon energy systems, and to identify key sustainable technologies within those futures.
3) Engage with current and possible future technology options throughout the gas value chain and across competing and synergistic energy vectors and technologies, to ensure that the analysis is grounded in engineering options in particular the synergies and differences between the UK and Brazil in gas.
4) Capacity building through a whole systems energy approach to address Ecosystem Services[6] across energy technologies associated with the development of a sustainable gas future
5) Develop common learning and understanding of the future of gas in both countries and worldwide supported by the Newton Fund, with a focus on research contributing to the economic development and welfare of Brazil as part of the Sustainable Gas Futures programme.

3. SCIENCE THEME PRIORITIES

The workshop identified eight science theme priorities that will help enable Brazil to maintain its desired percentage of low carbon energy in anticipation of a significant growth in domestic energy demand. Projects should build capacity by addressing at least three of the eight themes in order to promote the economic development and welfare of Brazil as the main objective of the research.

Although we acknowledge the different interests of both UK and Brazil parties (as identified in Appendix 1), proposers should base all submissions to the call on the Newton Fund and ODA requirements as given in section 4.1.

<u>Theme 1: Gas and Environmental Sustainability</u>

This theme emphasized the role of public permission to operate, transparency and communication and regulatory frameworks. The social license to operate was not regarded as a key issue for Brazil. However potential topics in this theme include both political and social dimensions. There are five potential areas to address:

a) Gas in the Energy Mix

- What intended and unintended consequences will a switch to gas have for natural capital resources in Brazil and the UK and global implications?
- Do we need gas for domestic energy; Renewables options?

b) Regulation of Gas

- Investigating the regulation of gas and its economic, social and environmental impacts.

c) Public and Political Awareness

- Explore and investigate public perception and education about gas and sustainability of energy.
- Investigate confirmation of social permission to operate.
- Investigate within an environmental risk framework (climate change, atmospheric methane, ground water contamination, and induced seismicity) how much offshore and onshore gas should be permitted for extraction?
- Explore public education concerning gas as a lower carbon fuel than coal.
- Market creation to move Brazilian culture towards the use of gas for heating/cooling/road fuel and not just cooking. Use of Gas in heating and domestic settings.

d) Financial mechanisms

- Develop fiscal mechanisms to encourage the use of gas in preference to other customary fuels.
- Developing cost benefit analyses which can be put in place before public engagement gets underway to avoid promising what can't be delivered.
- Investigating alternative accounting systems: Natural Capital Accounting, Ecosystem Services assessment, Social return on investment for cost, benefit quantification.
- Analysing the impact of natural gas on other low-carbon technologies.

- Investigating environmental trade-offs water, land use, biodiversity impact, CO_2 in Brazil and how to value them. Using lessons learnt from the UK?
- Investigating and comparing ecosystem and resilience services evaluation for megacities (Sao Paolo & London) health, well-being and happiness index.
- Engaging the full spectrum of stakeholders from Government, Regulators, NGs and public in these divers dialogues
- Understanding economic mechanisms to support low-carbon gas.

Theme 2: Novel Gas Processing

This theme concentrated on innovative technologies for the end-use of Gas including technologies other than direct Energy Generation. Three potential areas to address are:

a) Gas Storage Technologies Methane Gas Storage and Carbon Dioxide Sequestration

- Understanding binary systems with large scale seasonal storage with small-scale fast response storage to balance demand
- Investigating large scale offshore sub-sea storage and infrastructure (Both CO_2 and CH_4)
- Developing high-precision, multi-physics simulations of gas storage in geological reservoirs using industry simulators.
- Developing modelling of two-phase flow for optimization of liquefaction, storage and transport

b) Fuel Cells

- Solid oxide fuel cells with simultaneous CO_2 sequestration (CCS) potentially in coal horizons with enhanced coal bed methane production or in shale's as shale gas is removed and depleted
- Developing fuel cells for civil use in Brazil in domestic and business premises
- Development of fuel cells for small marine vessels

c) Gas as Petrochemical Feedstock

- Ethane and higher hydrocarbons as feedstock for crackers and for manufacture of ammonia and fertilizers; higher value products for transport and distribution without need for gas pipeline infrastructure
- Ethane and CO_2 conversion into road fuels/liquid fuels
- Large-scale use of gas in other chemical processes (chemistry/electrochemistry)
- CO_2 and CH_4 as new materials (fuels etc.) including process systems, economic and environmental implications

Theme 3: Innovative Technologies for Natural Gas Production

This theme concentrated on innovative technologies for the production of Gas including conventional and unconventional technologies. Four potential areas to address are:

a) Gas Production

- Investigate greener and more sustainable modus operandi for deep water gas production including transport and logistics management
- Design/manufacture and selection of innovative, environmentally friendly materials for offshore operations and gas processing which might include biodegradable drilling fluids, fracking fluids and packers as well as lower Carbon construction materials
- Optimisation of non-renewable oil and natural gas production with CO_2 driven Enhanced Oil Recovery (EOR) and Enhanced Gas Recovery (EGR) possibly linked with concomitant CO_2sequestration.
- Improved predictive modelling of process control of gas reservoirs.
- Develop pre-scale to field scale understanding of pore connectivity using molecular dynamics theory.

b) Shale Gas Resources

- Explore gas resource identification and robust resource evaluation
- Developing flow simulation models for shale gas extraction
- Investigating innovative hydraulic stimulation alternatives such as CO_2 fracking, cavitation Fracking, freeze-thaw cycle stimulation and waterless fracking.
- Why does so little of the hydraulic energy during fracking appear as fracture generation as determined using microseismicity (circa 1% or less) as a proxy? Can this be improved?

- Investigating shale gas optimal 'sweet-spot' identification and characterization to optimize efficiency of extraction
- Developing shale geomechanics theory and modelling.
- Research hybrid onshore to offshore shale gas development with infrastructure on shore and fracking offshore using long-reach horizontal drilling.
- Compare and contrast UK/Brazil offshore engineering experiences.

c) Hydrogen Pathways

- Investigating the process of offshore Underground Coal Gasification (UGS), to give SYNGAS (Carbon Monoxide, Methane and Hydrogen.
- Explore the separation of hydrogen as a transport fuel and combustion of remainder for energy generation, potentially offshore for sustainable deep-water platforms. With CCS of supercritical CO_2 in underground void space.

d) Sustainable Extraction Optimisation

- Developing an understanding of how to avoid fault revitalization and associated triggered earthquakes during shale gas fracking.
- Investigating water minimization of fracking and better use of produced water in conventional gas extraction, especially extraction of geothermal heat.
- Investigation and development of biodegradable drilling and fracking fluids.

Theme 4: Infrastructure

This theme looked at the role of gas in optimizing/simplifying energy infrastructures while reducing the carbon footprint. Six potential areas to address are:

a) Energy Integration

- Investigating gas and electricity gas as a base load to balance renewable energy generation.
- Exploring intelligent energy networks and interoperability.
- Investigating efficient, low carbon transmission using gas powered pumps etc.
- Developing a virtual workbench for simulation/modelling and predicting energy flows/demands and supply optimization.

b) Energy Network Infrastructure Optimisation

- Investigating integration of different energy providers and utilities for more efficient energy generation and distribution.
- Investigating offshore gas handling efficiencies.

c) Energy Generation

- Investigating and comparing offshore as opposed to onshore generation, with electricity rather than gas as the transport medium: 'Well to Wheels' concept.
- Developing localised liquefaction.
- Understanding the role of gas in the transition to a lower carbon energy system: i.e. decarbonizing heat.
- Investigating the use of heat from offshore produced water in Rankine (Binary Cycle) heat engines to help power offshore platforms.

d) LNG as alternative fuels

- Exploring the use of LNG transport (Cars/Ships/Aviation) fuel with lower emissions and less use of oil.
- Investigating the use of gas rather than heavy fuel oil to power marine vessels of a range of capacities and activities especially FPSO (Floating production storage and offloading facilities)

e) Gas Storage

- Investigating appropriate underground localities, environmental considerations, and connectivity to main infrastructure.
- Improving our understanding how to matching supply to demand.

f) Monetization of stranded gas reserves

- Comparing conventional versus unconventional economics.
- Investigating, what is the future value of gas if left in the ground?

Theme 5: Carbon Capture and Storage

This theme examined the role of Carbon Capture and Storage as potential routes to energy security with reductions in carbon load in the atmosphere.

a) Deployment

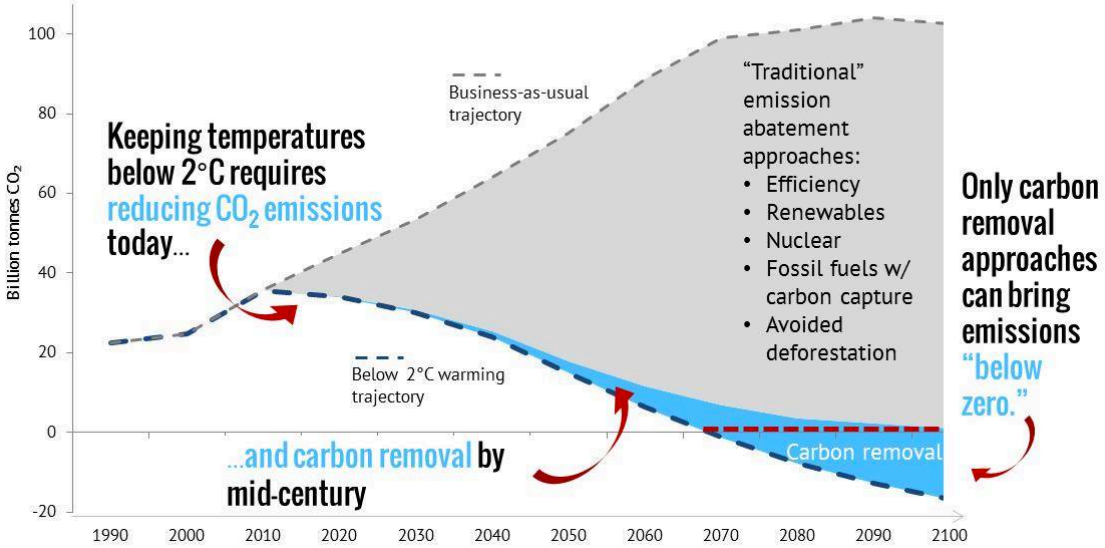
Research would be expected to compare and contrast economic and environmental evaluation of the costs and consequences of CCS in Brazil and the UK. It should address the potential spatial distribution (location) of deployment and the conditions needed to make it happen.

CCS is likely to be deployed earlier in the UK but, even if accepted (not universally) as an imperative to mitigate climate change, it is hugely capital intensive: lessons learned in the UK and EU should aid the setting of pathways in non OECD countries. Lessons learned would also help to de-risk future deployment.

Another aspect which could be investigated is the optimal re-use of expensive gas transport infrastructure. A key question would be: "how much will the cost of CCS have to fall to make gas use an affordable low-cost carbon solution?

b) Repositories for CO_2 storage

- Investigating the use of fractured horizons with enhanced permeability and absorption potential for storage of C02 post-Fracking in Shales or the Underground Coal Gasification Void-space.
- Comparing Geologies in UK/Brazil and their applicability for safe secure long-term storage.
- Chemical interaction between gas stored in saline aquifers and the rock matrix.
- Storage of Methane (Natural Gas) and Carbon Dioxide (Combustion Product of) in salt caverns, UK experience and technology transfer.
- Understanding whether offshore in the Santos Basin using solution mining is a preferable location
- Understanding and defining the maximum storage pressure compatible with cap-rock integrity confidence
- Lessons learnt from elsewhere for application to UK/Brazil.



adapted from the Climate Institute "Moving Below Zero" report

Theme 6: Assessment and Evaluation

From a natural environment perspective the use of gas for energy and its impacts on the ecosphere are a key consideration. There are four potential areas to address:

a) Is gas use compatible with climate change targets

- Comparing long-term versus short term bridging fuel.
- Investigating the conditions required for compatibility.
- Investigating gas as a base load to balance renewables energy sources.

- Investigating gas as a coal replacement, and how to make it happen.
- Exploring the possibility of substituting diesel with gas for road transport.
- Investigate whether gas can meet UK or Brazil energy demands in an acceptable ecological, environmental, and economical manner.

b) What is the land/water/ecosystems ecological footprint of:

- Understanding the ecological footprint of fracking for gas and gas distribution networks.

c) What lessons can be learnt for Brazil from UK infrastructure projects?

- Mapping future pathways and economics of lower carbon gas.
- Investigating the role of gas in energy and other services.
- Developing logistics and planning for reliability and eco-politic issues.
- Investigating the security of supply
- Understanding the governance of assets
- Comparing Megacities: Sao Paolo versus London, similarities and differences. Historic infrastructure versus new 'planned' development.

d) Fugitive Emissions

- Researching quantification of methane leakage from the supply and distribution networks.
- Researching the cost of mitigation of CO_2 and CH_4 gas leakages?
- The true relative contributions to environmental pollutants of gas versus coal including fugitive emissions, SO2 and particulates
- Avoidance of Flaring
- Comparing and contrasting costs both economic and environmental and the timescales.

Theme 7: Bioenergy and Gas

Brazil already has bioenergy as part of the energy mix and this theme has two main components to address:

a) Anaerobic Digestion and Biogas

- Investigating land-use, technology infrastructure and the implications/
- Research into microorganisms for biological gasification of organics including coal.
- Investigating all aspects of Waste Utilisation: Logistics, infrastructure, social acceptability, and impacts.
- Investigating the security of bioenergy and gas.
- Investigating demand and supply constraints.

b) BECCS (Bioenergy with Carbon Capture and Storage)

- Investigating BECCS as a potential negative carbon technology but with other constraints.
- Comparing and contrasting Biomass sources: Contrasts between Brazil and the UK
- Investigating resource constraints such as the water footprint for electricity generation, food competition and land utilization competition.
- Researching deforestation and loss of vegetative carbon storage capabilities.
- Investigating integrating bioenergy with natural gas and combined carbon capture and storage.
- Is this a possible and desirable route to rebalancing/eventual reduction in GeoGas usage in the context of land-usage and greenhouse gas emissions?

Theme 8: Social License to Operate

This theme raises two questions to address:

a) How do we evaluate relative importance of different stakeholder perspectives; Government, pressure group, NGOs, industry and the general public?

b) How to interrogate these different constituencies and how to merge points of view, which sometimes are diametrically opposing?

As examples, the workshop identified synergies between themes as follows:

1. Assessment and Evaluation + Bioenergy and Gas + Gas and Environmental Sustainability

2. Assessment and Evaluation + CCS + Infrastructure
3. Assessment and Evaluation + CCS + Novel Gas Processing
4. CCS + Innovative Technologies for Natural Gas Production + Infrastructure

4. NON-SCIENTIFIC PRIORITIES

1. Newton Fund (ODA requirements)

NERC and São Paulo Research Foundation (FAPESP) have developed the strategic science programme on Sustainable Gas Futures under the Newton Fund. The Newton Fund is an initiative intended to strengthen research and innovation partnerships between the UK and emerging knowledge economies. The Fund forms part of the UK's **Official Development Assistance (ODA)** commitment which is monitored by the **Organisation for Economic Cooperation and Development (OECD)**[7].

ODA funded activity focuses on outcomes that promote *long-term sustainable growth* and is administered with the promotion of the economic development and welfare of the partner country as its main objective.

The Fund covers 3 broad categories of activity:

- **people**: improving science and innovation expertise (known as 'capacity building'), student and researcher fellowships, mobility schemes and joint centres
- **programmes**: research collaborations on development topics
- **translation**: innovation partnerships and challenge funds to develop innovative solutions on development topics

The main research outcomes of the Sustainable Gas Futures programme must promote the economic development and welfare of Brazil.

2. Capacity building

A key element of the programme is capacity building and training. NERC is unable to fund studentships via this programme due to this being a three-year programme. FAPESP is able to fund scholarships under research initiatives proposed, improving capacity and trained researchers in the proposed areas, as a positive addition to the programme activities being carried out.

3. Knowledge Exchange

Knowledge Exchange(KE) will facilitate the communication of the science delivered from this challenge to a variety of users including policy makers and industry, and exchange of views and knowledge from these stakeholders with a view to enabling sustainable and environmentally acceptable economic growth in Brazil. There will be project level KE and this should be intrinsically linked to both the multi-/interdisciplinary partnerships and to stakeholder investments.

4. Programme Structure

The Sustainable Gas Futures programme is structured to ensure proposals for projects are of internationally excellent standard, whilst at the same time ensuring the main research outputs will promote the economic development and welfare of Brazil through a Sustainable Gas Future. This necessitates that projects within this effective multi-/interdisciplinary Programme build and maintain an effective UK-Brazil collaborative research partnership and that the research questions, implementation and outputs are co-produced.

Eight priority science themes (in no ranked order) were identified at the workshop to help ensure the future sustainability of the developing energy system in Brazil:

1. Gas and Environmental Sustainability
2. Novel Gas Processing
3. Innovative Technologies for Natural Gas Production
4. Infrastructure
5. Carbon Capture and Storage
6. Assessment and Evaluation

[7] http://www.oecd.org/

7. Bioenergy and Gas
8. Social License

Given the size of the available budget a single consortium project that addresses at least three of the eight priority themes would be appropriate.

Due to the limited budget available it is considered desirable and significantly advantageous if projects can benefit from co-funding or support from business.

5. Programme Management

A strong Programme Management is required to ensure the integration of all parts of the Programme to ensure a truly collaborative, effective multi-/interdisciplinary Brazil-UK research partnership.

APPENDIX 1: Sustainable Gas Futures

NOTES FROM THE NERC-FAPESP WORKSHOP, Sao Paulo 25-27 February 2015

Compiled on behalf of the attendees from rapporteur notes, by Professor Peter Styles, Keele University.

Introduction

A joint scoping workshop was help in Sao Paolo, Brazil, from 25 – 27 February 2015 under the auspices of FAPESP (Sao Paolo Research Foundation), the Natural Environment Research Council of the UK (NERC) and the NEWTON Fund. The objective was to discuss collaborative research collaboration in the area of Sustainable Gas Futures.

The goals and main aims proposed for the programme are outlined below.

Proposed goals for the Sustainable Gas Futures programme:

1) Develop new methodologies to characterise, explore, analyse and assess the role of gas in current and future energy systems, considering both economic and environmental sustainability indicators.

2) Deliver alternative views of the future of gas in low carbon energy systems, and to identify key sustainable technologies within those futures.

3) Engage with current and possible future technology options throughout the gas value chain and across competing and synergistic energy vectors and technologies, to ensure that the analysis is grounded in engineering options in particular the synergies and differences between the UK and Brazil in gas.

4) Capacity building through a whole systems energy approach to address Ecosystem Services across energy technologies associated with the development of a sustainable gas future.

5) Develop common learning and understanding of the future of gas in both countries and worldwide supported by the Newton Fund, with a focus on research contributing to the economic development and welfare of Brazil as part of the Sustainable Gas Futures programme.

Aims:

- To discuss the key science challenges that relate to the aims of this programme and how they could be best addressed.
- To facilitate networking, discussion and enable researchers to share ideas on key research questions relevant to the call.
- To explore opportunities for potential future collaboration in the area of whole systems approach to examining the use of gas in the energy system.

  The outcomes of the workshop will be used to define the scope of a new UK/Brazil, interdisciplinary call.

Day 1, 25th February 2015:

Presentation of Research Interests and areas of potential collaboration

The first full day (25th) was split into two sessions, the first of which was an open session held in the auditorium and organised around a series of themes as described in the following table. The second session was a closed meeting for the invited participants from both the UK and Brazil contingency.
Presentations were given by pairs of UK/Brazil participants as detailed:

Theme 1: Challenges for Oil and Gas Exploration, particularly in the Pre-salt Region Brazil: Dr Alvaro Maia, Petrobras UK: Prof Dorrik Stow, Heriot-Watt University
Theme 2: Energy System Deployment (opportunities/barriers) of Unconventional Hydrocarbons (eg Shale Gas/Oil) Brazil: Prof Ildo Sauer, University of Sao Paulo UK: Prof Peter Styles, Keele University
Theme 3: Transitions in Natural Gas Systems, including Transportation Brazil: Celso Morooka, CPETRO, Unicamp UK: Prof Peter Pearson, Cardiff University
Theme 4: Multi-Phase Fluid Flows in Reservoirs and Pipelines Brazil: Marcelo de Lemos, ITA UK: Dr Jeff Gomes, University of Aberdeen
Theme 5: Carbon Capture and Storage (CCS) including Bioenergy CCS (BECCS) Brazil: Dr Plino M. Nastari, Datagro Consultoria UK: Prof Jon Gluyas, Durham University
Theme 6: Environmental Change and Low Carbon Emission, including Policies and Research Brazil: Prof Claudio Oller, Poli-Eng Quimica UK: Prof Paul Ekins, University College London
Theme 7: Industry-Academy Interaction, Diffusion of Knowledge and Technology Transfer Brazil: Prof Julio R. Meneghini, University of Sao Paulo UK: Dr Adam Hawkes, Sustainable Gas Institute, Imperial College London

Day 2, 26th February 2015:

Invited participants only, detailed discussion of potential areas of interest and research collaboration.

Session 1:

The workshop participants were divided into mixed breakout groups in order to carry out the following tasks.

Activity	Type
1	**Identifying key science themes: breakout groups** This is an initial discussion to identify the high level research themes. - Participants divided into pre-organised groups. - In their groups they have to list out key science questions, challenges and opportunities for UK-Brazil collaboration. - Each group will self-nominate a rapporteur to capture the discussion on flip-chart and feedback.
2	**Identifying key science themes: marketplace** Individuals from different groups move around flip charts to allow them to see the notes of the discussions of the other groups and add comments on post it notes.
3	**Identifying key science themes: analysis and priority feedback** **Aim: Review all the groups' discussion results and cluster the challenges as themes and then prioritise the top 4-5 themes.** Each group to feedback their discussion via their rapporteur and these will be clustered for the next stage.
4	**Identifying key science themes: Voting** **Aim: Prioritise the top themes. Each participant will be given 5 sticky dots and asked to vote for their top 5 themes.**

Session 2:

The workshop participants were asked to sign up to a theme to develop further.

From the breakout groups the following research, knowledge exchange and cross-cuttings themes were identified. (The number of votes cast for each theme is given in brackets.) Delegates signed up to discuss each theme. Listed under Other Themes are themes which were proposed and voted upon, but had one or zero delegates signed up. Cross-cutting themes were discussed in the general discussion. Assessment and Evaluation, Bioenergy and Gas, Gas in the Context of Environmental Sustainability were combined into a single group.

Discussed Themes:

Group 1
Novel Gas Processing (15 votes)

Group 2
Innovative Technologies for Natural Gas Production (17 votes)

Group 3
Infrastructure (16 votes)

Group 4
Carbon Capture Transport, Storage (20 votes)

Group 5 – Combined interests
Assessment and Evaluation (20 votes)
Other themes:
Bioenergy and Gas (10 votes)
Gas in the Context of Environmental Sustainability (20 votes)

Social License to Operate (4 votes) – There was no interest in discussing social license as a separate issue and the groups were requested to take social implications into account as a crosscutting theme.

Novel Gas Processing

This theme concentrated on innovative technologies for the end-use of Gas including technologies other than direct Energy Generation. Three groups of technologies were discussed:

Storage

Gas Storage Technologies Methane Gas Storage and Carbon Dioxide Sequestration
Binary system with Large Scale Seasonal Storage with small -scale fast response storage to balance demand
Large Scale offshore sub-sea storage and infrastructure (Both CO2 and CH4)
High-Precision, Multi-Physics Simulations of Gas Storage in geological reservoirs using Industry simulators
Modeling of Two-Phase Flow for optimization of Liquefaction, Storage and Transport

Fuel Cells

i. Solid Oxide Fuel Cells with simultaneous CO2 sequestration (CCS) potentially in Coal horizons with Enhanced Coal Bed Methane production or in shales as shale gas is removed and depleted
ii. Fuel Cells for civil use in Brazil in domestic and business premises
iii. Development of fuel cells for small marine vessels

Gas as Petrochemical Feedstock

a. Ethane and higher hydrocarbons as feedstock for crackers and for manufacture of ammonia and fertilizers; higher value products for transport and distribution without need for gas pipeline infrastructure
b. Ethane and CO2 conversion into road fuels/liquid fuels
c. Large-scale use of gas in other chemical processes (Chemistry/electrochemistry)
d. CO2 and CH4 as new materials (fuels etc.). Process systems, economic and environmental implications

The participants suggested that the disciplines required to cover these topics included:

Chemists
Material Sciences
Process Engineers
Biologists
Chemical Engineers
Civil Engineers
Fluid Dynamics (Multi-phase flow)
Mechanical Engineers
Mathematicians
Physicists

Innovative Technologies for Natural Gas Production
This theme concentrated on innovative technologies for the production of Gas including conventional and unconventional technologies. Topics covered:

Gas Production
Greener and more sustainable modus operandi for deep water gas production including transport and logistics management
Design/manufacture and selection of innovative materials for offshore operations and gas processing
Optimisation of non-renewable Oil and Natural Gas production with CO2 driven Enhanced Oil Recovery (EOR) and Enhanced Gas Recovery (EGR) possibly linked with concomitant CO2 sequestration
Improved Predictive modeling of Process Control of Gas Reservoirs
Pre-scale to field scale understanding of pore connectivity using molecular dynamics theory.

Shale Gas Resources
Gas Resource identification and robust resource evaluation
Flow Simulation Models for Shale Gas extraction
Innovative Hydraulic Stimulation alternatives, CO2 fracking, Cavitation Fracking, Freeze-Thaw cycle stimulation. Waterless fracking.
Why does so little of the hydraulic energy during fracking appear as fracture generation as determined using microseismicity (circa 1% or less) as a proxy? Can this be improved?
Shale Gas optimal 'sweet-spot' identification and characterization to optimize efficiency of extraction
Shale Geomechanics theory and Modeling.
Hybrid onshore to offshore Shale gas development with infrastructure on shore and fracking offshore using long-reach horizontal drilling.
Complementary UK/Brazil offshore engineering experience

Hydrogen Pathways
Offshore Underground Coal Gasification to give SYNGAS (Carbon Monoxide, Methane and Hydrogen).
Separation of hydrogen as a transport fuel and combustion (with CCS of supercritical CO2 in underground void space) of reminder for energy generation potentially offshore for sustainable deep-water platforms

Sustainable Extraction Optimisation
Avoidance of Fault revitalization and associated triggered Earthquakes during shale gas Fracking
Water minimization if Fracking, Better use of produced water in conventional gas extraction especially extraction of geothermal heat
Biodegradable Drilling and Fracking Fluids

The participants suggested that the disciplines required to cover these topics included:

Chemists
Material Sciences
Process Engineers
Biologists
Chemical Engineers
Civil Engineers
Mathematicians
Physicists
Fluid Dynamics (Multi-phase flow)
Mechanical Engineers

Infrastructure

This theme looked at the role of gas in optimizing/simplifying energy infrastructures while reducing carbon footprint. Topics covered:

Energy Integration
Gas and Electricity: Gas as base load to balance renewable energy generation.
Intelligent Energy networks and interoperability.
Efficient, Low Carbon transmission using gas powered pumps etc.
Virtual Workbench for simulation/modeling and predicting energy flows/demands and supply optimisation

Energy Network Infrastructure Optimisation
Integration of different Energy Providers and utilities for more efficient energy generation/distribution
Offshore Gas Handling Efficiencies

Energy Generation
Offshore as opposed to onshore generation with Electricity rather than gas as the transport medium: Well to Wheels concept.
Localised Liquefaction
Understanding the Role of Gas in the transition to a lower carbon energy system: ie decarbonizing heat.
Use of heat from offshore produced water in Rankine (Binary Cycle) heat engines to help power offshore platforms.

LNG as alternative fuels
LNG use in transport (Cars/Ships/Aviation) fuel with lower emissions and less use of Oil.
Use of gas rather than heavy fuel oil to power marine vessels of a range of capacities and activities especially FPSO

Gas Storage
Appropriate Underground localities, Environmental considerations, connectivity to main infrastructure
Matching Supply to Demand

Monetization of stranded gas reserves
Conventional versus Unconventional economics
What is the future value if gas if left in the ground?

The participants suggested that the disciplines required to cover these topics included:

Marine Engineers
Naval Architects
Mechanical Engineers
Transport Strategists
Planning and Operational Management
Process Engineers
Economists

Carbon Capture Transport, Storage

This theme examined the role of Carbon Capture and Storage as routes to energy security with reductions in Carbon load in the atmosphere. Topics covered:

Economic and Environmental evaluation of costs and consequences of CCS in Brazil and the UK: Compare and Contrast.
Where, How to make it happen?

Likely to be deployed earlier in the UK: Even if accepted (not universally) as an imperative to mitigate climate change it is hugely capital intensive: Lessons learned in the UK and EU should aid the setting of pathways in non OECD countries and hopefully de-risk what will otherwise be seen as too difficult to implement

Optimal re-use of expensive gas transport infrastructure

Repositories for Storage
Investigate use of fractured horizons with enhanced permeability and Absorption potential for storage of C02 post-Fracking in Shales or the UCG Void-space.
Comparable Geologies in UK/Brazil and their applicability for safe secure long-term storage
Chemical interaction between gas stored in saline aquifers and the rock matrix
Storage of Methane (Natural Gas) and Carbon Dioxide (Combustion Product) of in salt caverns, UK experience and technology transfer.
Is offshore in the Santos Basin using solution mining the preferable location
Understand and Define maximum storage pressure compatible with cap-rock integrity confidence
Lessons learnt from elsewhere for application to UK/Brazil?

Economics
How much will the cost of CCS have to fall to make gas use an affordable low-cost carbon solution?

The participants suggested that the disciplines required to cover these topics included:

Geologists
Geophysicists
Petro-physicists
Petroleum Engineers
Completions Engineers
Financial Analysis
Chemical Engineering
Mechanical Engineering
Civil Engineering

Economics
Natural Sciences
Political Science
Social Sciences

Assessment and Evaluation
Topics covered:
Is Gas use compatible with Climate Change Targets?
Long-term v short term bridging fuel
Conditions for compatibility
Gas as base load/Balancing for renewables.
Gas as coal replacement/How to make it happen?
Substitution of diesel by gas for road transport.
Can gas meet UK or Brazil Energy demands in an acceptable ecological/Environmentally/Economically manner

The participants suggested that the disciplines required to cover these topics included:

Social Scientists
Communication Professionals
Political Scientists

Bioenergy and Gas

Topics covered:

Anaerobic Digestion and Biogas
Land-use implications/technology infrastructure implications
Microorganisms for biological gasification of organics including coal
Waste utilisation: Logistics/ Infrastructure/ Social acceptability/Impacts.
Demonstrable commitment to sustainability
Energy security
Demand and supply constraints

BECCS (Bioenergy with Carbon Capture and Storage)
Potential negative carbon technology but with other constraints
Biomass sources: Contrasts between Brazil (abundant?) and UK (sparse)
Resource Constraints: Water Footprint for Electricity Generation, Food competition and Land utilization competition.
Deforestation and loss of vegetative carbon storage capabilities?
Integrated bioenergy with natural gas and combined carbon capture and storage.
Route to rebalancing/eventual reduction in GeoGas usage?

The participants suggested that the disciplines required to cover these topics included:

Plant Scientists
Agronomists
Agriculturalists
Chemical Engineering
Economics
Natural Sciences
Political Science
Social Sciences

Gas in the Context of Environmental Sustainability

Topics covered:

What is the land/water/ecosystems ecological footprint of:
Fracking for gas
Gas Distribution Networks

What lessons can be learnt for Brazil from UK infrastructure projects?
Future pathways and economics of lower carbon gas?
Role of gas in energy and other services
Logistics and planning for reliability and eco-politic issues.
Security of supply
Governance of Assets
Megacities: Sao Paolo versus London, similarities and differences. Historic infrastructure versus new 'planned' development

Fugitive Emissions
Quantification of methane leakage from the supply and distribution networks.
Cost of mitigation of CO2 and CH4 gas leakages?
Environmental benefits or not? Particulates as well as CO2
Avoidance of Flaring
Costs economic and environmental and timescales

The participants suggested that the disciplines required to cover these topics included:

Engineering
Economics
Natural Sciences
Political Science
Social Science
Sociologists
Psychologists
Economists
Media/Communication
Engineering advisers
Electrical Engineers

Social License

How do we evaluate relative importance of different stakeholder perspectives/ Government/pressure group/NGOs/industry/general public?
How to interrogate these different constituencies and how to merge points of view, which sometimes are diametrically opposing?

The participants suggested that the disciplines required to cover these topics included:

Social Scientists
Communication Professionals
Political Scientists

The workshop participants suggested that groups of themes could be addressed together. Potential groupings where synergies could be exploited included:

- **Assessment and Evaluation**
  Bioenergy and Gas
  Gas in the Context of Environmental Sustainability

- **Assessment and Evaluation**
  Carbon Capture Transport, Storage
  Novel Gas Processing

- **Assessment and Evaluation**
  Carbon Capture Transport, Storage
  Infrastructure

- **Innovative Technologies for Natural Gas Production**
  Infrastructure
  Carbon Capture Transport, Storage

Discussion of potential programme structures

Given the size of the available budget, there was discussion at the workshop around the scope of the call. One idea is that the programme could fund Proof of Concept studies in all of the eight priority themes, or one approach would be to have a single consortium project that addresses at least three of the eight priority themes. The final decision on which approach to be adopted depends on a variety of considerations including financial resources and timing. NERC and FAPESP will take these factors and the workshop discussion into consideration when making the decision on the structure of the call.

APPENDIX 2: NOTES ON THE BIS NEWTON FUND

The Newton Fund is an initiative intended to strengthen research and innovation partnerships between the UK and emerging knowledge economies, developing partner countries long-term sustainable growth and welfare through building research and innovation capacity.

The Fund forms part of the UK's Official Development Assistance (ODA) commitment which is monitored by the Organisation for Economic Cooperation and Development (OECD). ODA funded activity focuses on outcomes that promote the long-term sustainable growth of countries on the OECD Development Assistance Committee list and is administered with the promotion of economic development and welfare of developing countries as its main objective. Newton Fund countries represent a sub-set of this list.

The Newton Fund requires that the funding be awarded in a manner that fits with ODA guidelines. All applications must therefore be compliant with these guidelines. Note that this applies to UK funding only, and not the partner country, however as these are collaborative projects, it's expected that the project as a whole is ODA compliant and makes clear that its primary purpose is to promote the economic development and welfare of the partner country. For further information of Newton Fund see http://www.rcuk.ac.uk/ international/newton/

Any Newton Fund project must make it clear how the main research outcomes will promote the economic development and welfare of the partner country, rather than merely creating the conditions where development might occur. Applicants should consider how their project will:

- Address poverty and development issues
- Address the issue identified effectively and efficiently Use the strengths of the UK to address the issue
- Demonstrate that the research component is of an internationally excellent standard.

It is expected that through collaboration the projects should seek to increase the skills and knowledge base at the partners institutions in this area, improving their ability to undertake and disseminate research in order to maximise the countries impact on issues of poverty and economic growth.

Any benefit to the UK has to be the secondary consideration and should not lead to a project being funded if it doesn't primarily deliver the development objective.

The AO must clearly state that applicants should address ODA compliance (economic development and welfare of developing countries) in both the JeS summary and then more fully, in the case for support.

Capital requests

It should be stated within the AO that requests for capital will only be considered if the proposed equipment is to remain in the partner country for use after the project is completed. If equipment is returned to the UK after the project this cannot be funded through Newton and an alternative source of funding should be sought.