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NIA Project Registration and PEA Document

Date of Submission

Oct 2018

Project Reference Number

NIA_CAD0029

Project Registration

Project Title

Blended Hydrogen and Compressed Natural Gas for Transport

Project Reference Number

NIA_CAD0029

Project Licensee(s)

Cadent

Project Start

October 2018

Project Duration

2 years and 5 months

Nominated Project Contact(s)

Cadent Innovation Team

Project Budget

£254,300.00

Summary

The proposed project has three phases:

- Phase 1: Project definition: Complete a literature review, consultation with truck OEMs, and collation of existing data/research to develop a detailed understanding of current position with respect to use of blended methane/hydrogen mixes in heavy transport/HGV applications. This will highlight issues to be investigated in Phases 2 and 3 with regard to gas engine operation and control systems.
- Phase 2: Project Planning and Design; Detailed planning of engine test and combustion modelling tasks and confirmation of the feasibility of conversion of the University of Brighton Euro VI single cylinder Diesel engine to Spark ignited methane fueling.
- Phase 3: Single cylinder engine test and modelling work: Engine test and modelling work will be performed to investigate the effect of varying hydrogen concentrations on combustion efficiency and emissions at varying engine speed, load and air/fuel ratio and to simulate performance over a drive cycle to understand real world effects.

Nominated Contact Email Address(es)

Innovation@cadentgas.com

Problem Being Solved

To meet 2050 targets for reduction of GHG emissions, significant progress is required in both heat and transport sectors. The HyNet programme Cadent is involved with, seeks to address this challenge in both sectors through the addition of hydrogen to the gas network. Existing projects address commercial arrangements for this development (NW hydrogen (HyNet) cluster - NIA_CAD0015) and the impact on CHP applications (DNV programme - NIA_CAD0009) however evidence examining the impact of this activity on transport is currently incomplete.

Reducing GHG emissions, and in particular improving air quality is now a UK Government imperative following recent Climate Earth ruling. While electrification is expected to provide a useful route to decarbonisation of passenger transport, electrification of heavy duty vehicles is challenging due to high power and range requirements. Consequently, this sector is generally recognized as one of the most difficult to decarbonise.

One of the options seeking to address these challenges is methane fueled engines which are gaining market share for heavy duty vehicles due to perceived benefits in reducing fuel costs, emissions and noise. This project will deliver evidence of the impact of plans to introduce hydrogen into the gas fuels on heavy duty transport by developing fundamental understanding of the influence of varying

concentrations of hydrogen on combustion in heavy duty, methane powered Euro VI engines. Previous work in this area has mainly focused on light duty engines, with analysis of the performance of heavy duty engines fragmented and generally unrepresentative of current Euro VI engines. Development of evidence of the performance of these engines on methane/hydrogen blends will reduce risk associated with the HyNet project through providing evidence of likely acceptability for the transport sector. Along with complementary NIA studies, this work will produce data sets that can be used to support the definition of new acceptable network standards/limits (current standard 0.1%mol of hydrogen).

Method(s)

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- Phase 1: Project definition: Complete a literature review, consultation with truck OEMs, and collation of existing data/research to develop a detailed understanding of current position with respect to use of blended methane/hydrogen mixes in heavy transport/HGV applications. This will highlight issues to be investigated in Phases 2 and 3 with regard to gas engine operation and control systems.
- Phase 2: Project Planning and Design; Detailed planning of engine test and combustion modelling tasks and confirmation of the feasibility of conversion of the University of Brighton Euro VI single cylinder Diesel engine to Spark ignited methane fueling.
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Scope

The following high level tasks are proposed:

- Task 1: Project overview;
 - o Consultation with academia, truck OEMs and suppliers etc. to understand previous research/development activities in this area (speak to Iveco et al)
 - o Establish an expert advisory panel to support the research programme (including OEMs, CCC, Ricardo, APC and academic partners TBC.)
- Task 2: Test programme definition
 - o A comprehensive literature review and consultation with academic and industrial members of the project advisory board will support detailed planning of engine test and combustion modelling tasks
- Task 3: Hardware definition
 - o Work will be undertaken to confirm the feasibility of conversion of Euro VI single cylinder Diesel engine to Spark ignited methane fueling, and to finalise test cell fueling arrangements
- Task 4: Procurement and engine commissioning
- Task 5: Single cylinder engine test
 - o Engine test work will be performed to investigate the effect of varying hydrogen concentrations on combustion efficiency and emissions at varying engine speed, load and air/fuel ratio. A Design of Experiments approach will be used to investigate the influence of multiple variables.
- Task 6: Data analysis
 - o Data will be collated, checked and analysed to develop understanding of varying hydrogen composition on combustion efficiency and emissions
 - o Results will be compared to the baseline Diesel case and previous UoB work on Diesel -Hydrogen combustion
- Task 7: Develop combustion models
 - o Modelling work will be carried out to investigate the fundamental mechanisms of methane/hydrogen combustion, work will aim to achieve acceptable correlation between modelled performance and engine test data
- Task 8: Simulate real world duty cycles
 - o Models will be used to simulate engine performance over a wide range of speed/load conditions to simulate performance over a real world drive cycle
- Task 9: Development of a Roadmap to understand future deployment
 - o Develop recommendations based on project findings and discussion with Cadent and the Advisory Board. These recommendations will focus on:
 - o Barriers to use of natural gas and hydrogen blends in above transport applications
 - o Future technology developments that may be required to enable use of high hydrogen blends (this could extend to engines, control systems, and on-board fueling equipment etc.)
 - o The UoB team will then develop final detailed reports and summary presentations for internal use by Cadent.

Objective(s)

The overarching objective of the project is to provide evidence of the effect/impact of introducing hydrogen into the gas supply on natural gas fueled transport applications (especially methane engines used in HGVs).

The project will have a number of task-oriented sub-objectives;

- Produce data sets of the impact of hydrogen on gas engine operational performance when used in transport/heavy freight vehicle applications
- Provide guidance on the potential hydrogen limit that should be considered regarding use of natural gas/hydrogen blends in gas engine transport/heavy freight vehicle applications
- Identify any barriers to use of natural gas and hydrogen blends in above transport applications
- Develop understanding of future technology developments that may be required to enable use of high hydrogen blends (this could extend to engines, control systems, and on-board fueling equipment etc.)

Output will also inform HyNet, HyNet Motion, HyPurity and HyDeploy NIC projects in relation to potential hydrogen content limits. Consider presenting results at the IGEM Gas Quality Working Group (IGEM GQWG).

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

Success criteria for this project are:

- Engine test work demonstrates the influence of hydrogen/methane dual fueling on combustion efficiency and emissions for a Euro VI relevant Heavy duty engine
- Combustion models enable the simulation of hydrogen/methane fueled engine performance over a real world drive cycle
- The project provides recommendations on likely acceptability of hydrogen/methane fueling for Heavy Duty transport

Project Partners and External Funding

Project partners: DNV

Project advisory panel: APC, Iveco, Ricardo, academic members TBC

Potential for New Learning

Work to date on the influence of hydrogen on methane combustion is generally focused on light duty engines that do not comply with recent emission regulations, and typically examine a limited range of engine operating conditions. This work will examine the performance of a Heavy duty engine of Euro VI specification, and will use modelling to ensure that the influence of hydrogen addition over a real world duty cycle can be demonstrated.

Learning developed in the project will be disseminated through academic papers (with agreement from Cadent), presentations at events such as the Low Carbon Vehicle Show and Future Powertrain Conference, discussions with industrial partners, and University of Brighton's Advanced Propulsion Centre spoke network. Output will also form an input into the Transport Energy Network that University of Brighton is currently initiating in collaboration with Automotive Council, LowCVP and the Advanced Propulsion Centre.

Scale of Project

The approach selected represents the most cost effective way of investigating the combustion characteristics for methane/hydrogen fuels blends and thereby reducing the risk associated with existing methane fueled vehicles. The most expensive part of any combustion engineering programme is engine test work. In this programme, single cylinder testing is used to provide fundamental understanding of combustion mechanisms, while avoiding the complexity (and fuel costs) of a multi-cylinder test programme. The length of the test programme will be reduced by limiting the number of engine operating points and using combustion models (correlated to the engine test results) to model performance across the engine speed/load range and thereby understand engine operation over a real world duty cycle. Correlation of models with test data is vital to providing confidence in this area, where the modelling of the combustion of such fuel blends is still developing.

The project will leverage recent investment in test facilities at University of Brighton by the APC MUSTER programme, which has supported the purchase of state of the art emissions and combustion measurement equipment. Work will also benefit from UoB previous experience in testing dual fueled engines gained during an Innovate UK project in collaboration with Ricardo investigating hydrogen/Diesel blends.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL3 Proof of Concept

Geographical Area

The work will be relevant for territories where Euro emissions standards are in force, further work would be needed to understand the influence on engines conforming to US standards.

Revenue Allowed for the RIIO Settlement

No

Indicative Total NIA Project Expenditure

External Cost - £170,000

Internal Cost - £61,200

Contingency - £23,100

Total Cost - £254,300

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

n/a

How the Project has potential to benefit consumer in vulnerable situations:

n/a

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

The project in itself will not provide a cost reduction to customers directly, but will provide evidence of the impact of a proposed approach to decarbonisation of the transport sector using a least cost pathway.

Please provide a calculation of the expected benefits the Solution

This project in itself will not provide a financial benefit. However, this piece of work will provide evidence of the impact of a proposed approach to decarbonisation on the transport sector. Customers will then have the opportunity to benefit from the decarbonisation within the UK via the least cost pathway.

Please provide an estimate of how replicable the Method is across GB

This work will be applicable to countries where Euro emissions regulation are in force

Please provide an outline of the costs of rolling out the Method across GB.

N/A

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

- A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).
- A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)
- A specific novel operational practice directly related to the operation of the Network Licensees system
- A specific novel commercial arrangement

RIIO-2 Projects

- A specific piece of new equipment (including monitoring, control and communications systems and software)
- A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven
- A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)
- A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology
- A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution
- A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

Learning from this project is relevant to all UK national gas networks. New learning could be used to inform other Hydrogen/Methane projects in the UK.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

This project will provide supporting evidence for the impact of hydrogen methane blends on transport applications, and is therefore an enabler for a material reduction in carbon emissions through a hydrogen blend being injected into the domestic network.

- Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

Is the default IPR position being applied?

- Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

There are a number of application areas that may be affected by the addition of hydrogen to the gas grid, e.g. domestic heat and cooking, transport, combined heat and power. This project will look specifically at transport applications and while there is some similarity with CHP applications (similar engine swept volume) other aspects are different, principally transient operation. This project will therefore work closely with the current DNV CHP project (NIA_CAD0009), to ensure the learning from the CHP project is incorporated into the current project (e.g. on gas quality) and that the projects are complementary (i.e. this project focuses on a wider range of operational conditions)

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

n/a

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

Work to date on the influence of hydrogen on methane combustion is generally focused on light duty engines that do not comply with recent emission regulation, and typically examine a limited range of engine operating conditions. This work will examine the performance of a Heavy duty engine of current Euro VI specification, and will use modelling to ensure that the influence of hydrogen addition over a real world duty cycle can be demonstrated. The need for the project is new, predicated by the increasing uptake of methane fueled vehicles in the heavy duty sector and innovative plans by Cadent to decarbonise heat and transport through the addition of hydrogen to natural gas supply.

Relevant Foreground IPR

n/a

Data Access Details

n/a

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

Hydrogen conversion of the domestic grid and heavy industry due to having a full CCS chain in operation cannot be considered business as usual. This will present a step change for the UK gas industry if achieved and could future proof the gas grid for many decades to come.

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

The project requires NIA support to overcome the following risks: Technical risks include understanding Feasibility of converting Euro VI single cylinder Diesel engine to spark ignition methane fueling and validation of engine modelling/simulation of hydrogen/methane blends.

This project has been approved by a senior member of staff

Yes