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PROJECT REPORT – 22nd March 2019

Transport-Technology Research Innovation
for International Development (T-TRIID)

# Low Carbon Hyderabad Bus Fleets

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**Company Name of Grant Recipient:** Water Fuel Engineering Ltd.

HIGH VOLUME TRANSPORT
APPLIED RESEARCH

UKaid
from the British people

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## List of tables and figures



## List of acronyms and abbreviations

| | |
|---|---|
| CO | Carbon monoxide |
| DFID | UK Department for International Development |
| DPF | Diesel Particulate Filter |
| GHG | Greenhouse gas; i.e. Gases which contribute to global warming |
| GPS | Global Positioning Satellite |
| $H_2O$ | Water |
| HHO | Oxyhdrogen or 'Brown's' gas |
| HSU | Hartridge Smoke Units |
| ICE | Internal Combustion Engine |
| LICs | Low Income Countries |
| NOx | Nitrogen oxides |
| TSRTC | Telangana State Road Transport Corporation |
| T-TRIID | Transport-Technology Research Innovation for International Development |
| UBHC | Unburnt hydrocarbons |
| UK | United Kingdom |
| WFE | Water Fuel Engineering |

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## Executive Summary

To tackle the issue of rising greenhouse gas (GHG) emissions in developing countries, the UK Department for International Development (DFID) launched the Transport-Technology Research Innovation for International Development (T-TRIID) under the High Volume Transport Applied Research Programme.

The *Low Carbon Hyderabad Bus Fleets project* was a six-month research project undertaken from October 2018 to March 2019, led by Water Fuel Engineering (WFE) in collaboration with Telangana State Road Transport Corporation (TSRTC) based in Hyderabad, India. The aim of the project was to reduce the tail-pipe emissions of twenty-year old public transport buses. TSRTC has one of the largest bus fleet in the world, consisting of 10,525 vehicles.

WFE is a company striving to create a cleaner and more efficient use of energy in the future. Established in 2013, WFE specialises in the research and development of alkaline electrolysers which can be used commercially, domestically or industrially to improve the combustion efficiency of conventional fuels.

The *HydroGen™* is an autonomous electrolyser that is powered by an alternator, using an average of 6 to 12 amps. By splitting water ($H_2O$) into its two component gases, this unique system delivers an amalgamated gaseous mixture of hydrogen and oxygen to any engine via the air intake to accelerate the combustion speed of carbon-based fuels. The result is more energy being released and lower levels of polluting emissions, soot and particulates being produced when using fuels such as diesel or petrol.

Thanks to the T-TRIID grant, WFE has been able to successfully complete road trials in India in collaboration with the Telangana State Road Corporation. The retrofitting of oxyhydrogen electrolysers to six buses, aimed to demonstrate the ways in which this technology can reduce emissions on older, conventional diesel vehicles. In low income countries (LICs), alternative fuels and comprehensive fleet upgrades are unaffordable. Developed countries too are struggling to identify alternatives to diesel for heavy duty usage.

The project exposed WFE to the challenges of exporting, customs clearance, excise duties and documentation. The geography (working 5,000 miles from our base), climate (working in temperatures of up to 35C), culture (working with partners of a different mind-set), each added to the challenges. However, WFE staff were enriched and empowered by the experience, rendering the company as a whole, better equipped to take this project to the next stage.

Although the project was conducted exclusively in Telangana State, WFE were mindful of DFIDs objectives to reach out to all LICs in the pursuit of improved air quality. Consequently, partners across India have been identified and collaborations in Jordan and Sri Lanka have also commenced in principle. As this report will demonstrate, scaling up to reach out to all LICs is entirely possible.

The project in Telangana has attracted the support of Indian investment company, Tavasya Venture; with the promise of investment and support. Initial discussions with their Head of Business Development has resulted in a Letter of Intent. (Appendix 2).

The momentum generated by this project and the support received from T-TRIID (and from Gary Haq in particular), has enabled WFE to both deliver on and exceed expectations as laid out in the DFID guidelines.

Moreover, the results of the trials themselves have validated the theories behind the technology and established the effectiveness of retrofit electrolysers in matching emissions in the laboratory (80%), with emissions reductions in real-world conditions (75.4%).

Although two of the units malfunctioned, the lessons learned will enable further improvements to be made to the systems. Challenges due to the extreme weather conditions in India had been anticipated, however the trial revealed several additional weaknesses in the systems that can now be corrected; modifications that will deliver reliable, market-ready units for countries throughout the world.

The four units that completed the trials delivered consistent emissions reductions averaging 75.4%; Just 4.6% below target levels that had been reached in laboratory conditions. The two dimensions to the emissions tests (HSU 'opacity' and kVal - 'mean' value calculation), again provided evidence of the integrity of the analysis by delivering comparable data within 3 percentage points of each other. The emissions testing was undertaken independently by a Government of India inspection team and certified accordingly. (Appendix 1)

Fuel consumption was monitored by TSRTC, who reported no significant savings. Whilst this was disappointing, it is most likely reflected by the anomalies within the TSRTC processes themselves which were manually undertaken and loosely recorded. Variations in driver performance accounted for variations in fuel consumption of 65.1%, so identifying savings of 10% would always be a challenge. However, unlike emissions analysis, fuel efficiencies are easily monitored and verified, and we stand by the results obtained elsewhere which have never fallen below 8% improvement levels.

With emissions results established along with the interest of funding partners in India, the potential for the WFE electrolyser across LICs is immense.

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# 1. Introduction

Transport sector greenhouse gases (GHG) have grown at a rate faster than any other sectors over the past half century[1]. Low carbon transport is therefore essential if global climate targets are to be met. This is particularly the case in emerging economies such as India which is experiencing rapid motorisation. Thirteen out of the 20 most polluted world cities are in India leading to more than 650,000 premature deaths each year and it is getting worse (OECD, 2014; WHO, 2018). In the period 2001-2013, India's carbon emissions increased by 137 per cent (WHO, 2018).

Much of India's public transport bus fleets are more than twenty years old, with many pre-owned buses coming from affluent European countries as the West upgrade their own fleets. The high costs of purchasing newer vehicles means that older vehicles will continue to be a major part of the Indian transport sector for the foreseeable future. A retro-fit solution is therefore essential if ambitious national air quality standards (BSVI) are to be met by 2020.

To tackle the issue of rising GHG emissions in developing countries, the UK Department for International Development (DFID) launched the Transport-Technology Research Innovation for International Development (T-TRIID) under the under the High Volume Transport Applied Research Programme.

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## 1.1. *Water Fuel Engineering Ltd*

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The *HydroGen™* is an autonomous electrolyser that is powered by an alternator, using an average of 6 to 12 amps. By splitting water ($H_2O$) into its two component gases, this unique system delivers an amalgamated gaseous mixture of hydrogen and oxygen to any engine via the air intake to accelerate the combustion speed of carbon-based fuels. The result is more energy being released and lower levels of polluting emissions, soot and particulates being produced from using fuels such as diesel or petrol.

The system is unique as it addresses emissions at the pre-combustion stage. This is different to diesel particulate filters (DPF) or additives such as Ad-Blu which attempt to capture or chemically alter toxic exhaust fumes once they have been created. *HydroGen™* is retro-fitted in less than a day, requires no adjustment to engines, and is not limited to the size or capacity

[1] IPCC: https://www.ipcc.ch/sr15/

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of the engine. The operating temperature, pressure, voltage and current of the electrolysers are regulated by an electronic control unit, which also provides a fail-safe against an insufficient level of electrolyte or malfunction of the system. There is no storage of oxyhydrogen at any point, and the produced volume of gas is determined by the requirements of the engine.

The purpose of *HydroGen*™ is to enable conventional vehicles to produce fewer emissions and thereby reduce the urgency for them to be replaced. It is a way for fleet operators to continue to use their existing fleet whilst also reducing their carbon-footprint without the need for large-scale investment or replacement of stock.

### 1.1. *Objectives of the Project*

The project aimed to evaluate the performance of oxyhydrogen electrolysers in Indian diesel buses. WFE has consistently achieved opacity, smoke and overall emissions reductions of 80 per cent in controlled environments, and although we have little data to profile these reductions, it seems reasonable to deduce that at such levels our system is making a positive contribution to air quality improvements. We are also able to deliver fuel savings of between 8-25 per cent, which is supported by academia.[2] However, the challenge is to replicate such achievements in passenger transport in polluted world cities struggling to address poor quality. The aim is to achieve reductions in polluting tail-pipe emissions and fuel savings in practical road trials, as well as making potential further adjustments to the electrolysers to improve performance.

The project also involved knowledge transfer, where TSRTC engineers received training on the functioning, installation and upkeep of WFE's *HydroGen*™ electrolysers. Such collaboration demonstrated the commitment to future partnerships and application of the technology in India. The installations took place across a two-week period, and the performance of the vehicles across ten weeks was to be compared to the baseline data taken prior to the installations.

The effectiveness of the electrolyser operating in extreme sub-tropical regions was also to be monitored with the aim of taking it to the next stage once the concept is proven; enabling low income countries (LICs) to benefit from the technology.

## 2. The HydroGen™ Electroylser

Electrolysis is not a new concept. Producing oxygen and hydrogen has been the subject of many high school physics experiments involving a battery and a couple of nails (see

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**Figure *1***).

However, the cost of the electricity required to split water into its constituent gases outweighed the benefits and has prevented its widespread commercial application as an alternative energy source.[2]

[2] Evgeni Dimitrov, Deyan Deltchev, Vladimir Serbezov, Spas Pantchev 'Research of oxyhydrogen gas mixture influence upon diesel engine performance', 1Technical University – Sofia, Department of Combustion Engines, Automobile Engineering and Transport, New Energy Corporation Ltd, Technical University – Sofia, Department of Air Transport p.2-4.

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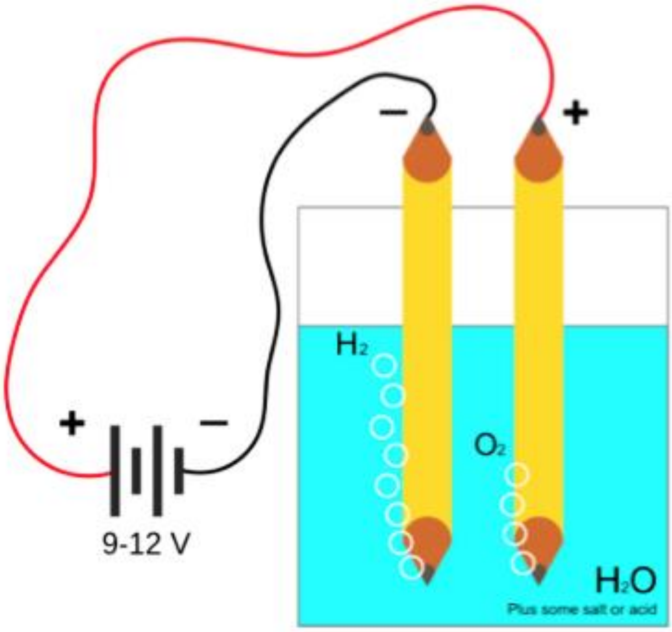


**Figure 1:** A simple electrolysis experiment

Over the past decades, researchers have explored the chemical reaction which results from oxyhydrogen (HHO) being mixed with fossil fuels in an internal combustion engine (ICE). In particular, Indian researchers have contributed to this innovation therefore enhancing the prospect of local uptake. Patil et al. (2017) investigated HHO generation based on Faraday's law by supplying electricity to electrodes or plates of the same material, along with gas generation using direct current pulses.[3]

The generated gas was introduced without any engine modifications to a Honda GX-160CC engine. The researchers verified the supplementary nature of HHO and concluded that HHO gas will always have a positive effect on performance.[4] Such research shows that an increase in thermal and fuel efficiency is a direct result of the addition of HHO along with the energy required to produce certain volumes of the gas.[5]

Table 1 and Table 2 can be used to indicate the required energy to produce certain volumes of HHO, along with the anticipated differences the gas causes to fuel economy and engine performance.

[3] N N Patil e*t al*, 'Generation of oxy-hydrogen gas and its effect on performance of spark ignition engine', *IOP Conference Series: Materials Science and Engineering* (2017), p.4.
[4] *Ibid*, p.12.
[5] *Ibid*, p.9.

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***Table 1**: Relationship between level of supply current and brake thermal efficiency*

| Current supplied (Amps) | % increase in Brake thermal efficiency |
|---|---|
| **6A** | 2.36% |
| **7A** | 3.146% |
| **8A** | 4.464% |
| **9A** | 10.801% |

**Table 2:** Relationship between level of supply current and fuel savings

| Current supplied (Amps) | % reduction in fuel consumption |
|---|---|
| **6A** | 5.418% |
| **7A** | 6.40% |
| **8A** | 7.39% |
| **9A** | 10.83% |

Source: Patil et al (2017)

Furthermore, the addition of HHO also results in a reduction in harmful emissions. The work of engineers at Anna University in Chennai[6] focus on the use of Brown's gas (HHO) in spark ignition engines and combustion ignition engines. They conclude that unburned hydrocarbons (UBHC) can be reduced by as much as 91% when the fuel is combusted in HHO (see Figure 2).

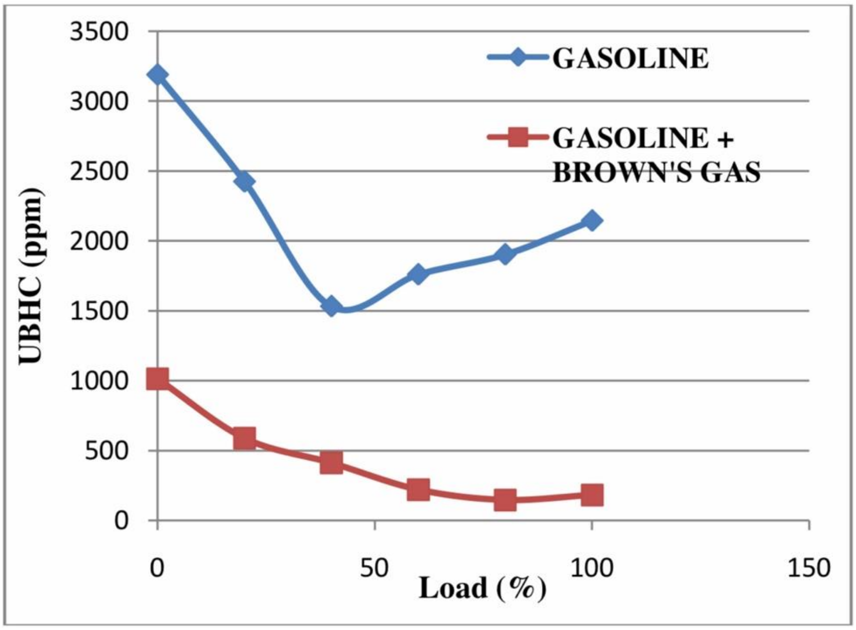


**Figure 2:** Comparison of Unburnt Hydrocarbon

Source: Leelakrishnan et al (2013)

[6] E Leelakrishnan, N Lokesh, H Suriyan, 'Performance and Emission Characteristics of Brown's Gas Enriched Air in Spark Ignition Engine', Anna University, Chennai, p400

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Researchers referenced in this report agree that producing HHO on board vehicles overcomes the problems of storage. However, they cast doubt over whether sufficient HHO can be generated using the vehicles on-board electricity supply. As shown by Patil et al (2017) (see Figure 3), they manage to produce about 120ml of HHO per minute at 9amps

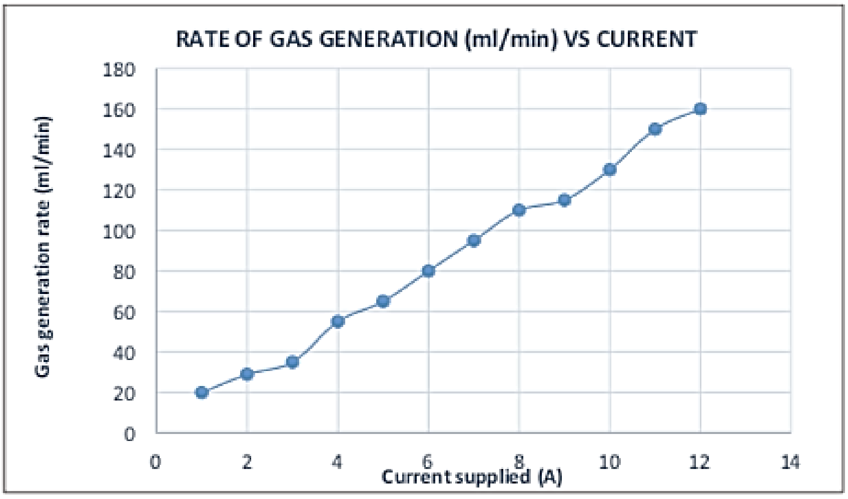


**Figure 3:** Gas generations with different inputs

Source: Patil et al (2017)

Patil et al (2017) acknowledge that the method incorporating direct current pulses could generate more HHO but conclude that it has limitations due to 'complex design, bulky structure and large space' which is required for its installation.[7]

However, as outlined below, WFE's technological advances have enabled them to deliver a 'Pulse Electrolyser' which avoids the need for a 'bulky structure' or a 'large storage space' which, although 'complex', has nevertheless been completed within realistic cost levels, and delivers the benefit of greater gas production for the same electrical input. As a result, production levels of HHO can be improved dramatically offering greater sophistication for the vehicle's specific drive cycle. This innovative departure from convention is a unique aspect of the work of WFE.

The "limitations" (outlined by Patil et al above) outlined within such research, along with other references at the end of this report, are used to direct the development strategy of the *HydroGen*™. Confronting and resolving identified technological restrictions is at the forefront of the methodology used to advance the technology and is demonstrated by the innovative nature of the electrolysers.

[7] *Ibid.*,p.5.

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The research of Patil et al. (2017), Leelakrishnan et al (2013) and others has provided the scientific theories and applications for the work of WFE. For example, Leelakrishnan et al. reaffirm the complex and unique nature of HHO, (which they refer to as Brown's Gas) on page 394 of their paper "Performance and Emission Characteristics of Brown's Gas Enriched Air in Spark Ignition Injection", stating "Brown's gas is a mixture of monatomic and diatomic hydrogen and oxygen and a special form of water called Electrically Expanded Water (EEW), or Santili Molecules…Brown's gas has a plethora of unusual characteristics that seem to defy current chemistry"

## 2.1 Innovation

The *HydroGen*™ is compact and the small dimensions of the units enable them to widen the potential sphere of application. Through using pulse electrolysis (thereby creating resonance within the electrolyte), the electrolysers weaken the neutron bonds between the oxygen and hydrogen atoms. Such a method reduces the amount of electricity required to produce a larger volume of gas (see **Error! Reference source not found.**).

In our own laboratories the *HydroGen*™ electrolysers produce 10 litres of HHO per minute using 9 amps, which research has correctly indicated is the maximum energy than can be obtained from a vehicle without impacting other functionalities. This efficiency is sixty-seven times higher than the one stated by Patil et al. (2017) when using the same current (see Figure 3). Although we have not had these levels independently verified, they are easily measured and our claims can therefore be made with absolute confidence. *HydroGen*™ can deliver greater fuel savings along with higher polluting emissions reduction as more of the inherent energy present in fossil fuels is released more effectively, with less carbon remaining to create carbon monoxide (CO) or $CO_2$.

Even though numerous internal tests have been conducted in order to provide the figures, mentioned above, we still lack an independent evaluation from a third party in order to verify our results. Cost is a major factor, but standardisation is the main reason. One method of testing cannot be applied to all engines, due to manufacturing and design variations. Moreover, as emissions testing is almost entirely conducted on the basis of algorithms, existing state-of-the-art analysis systems are unsuitable for retro-fit technology as they are designed around the 'normal' functioning of the engine. Conducting tests to certify the technology for all engine types is an area for future collaboration.

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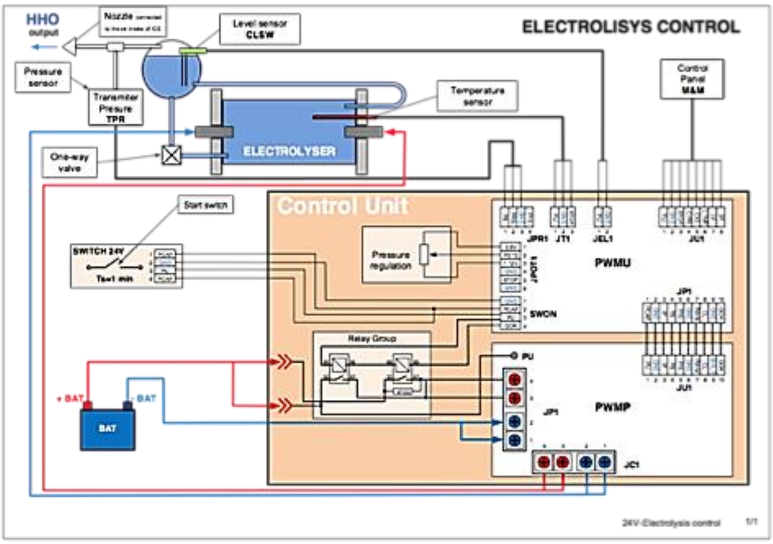


**Figure 4:** WFE circuit diagram of electrolyser and control unit

The wider academic awareness created by engineers in India referenced above, as well as those at Sofia's Technical University has also motivated WFE to exploit the benefits of hybridising oxyhydrogen with diesel.[8], The unrivalled energy density of diesel remains attractive as a fuel source for larger vehicles, and the compatibility of *HydroGen*™ with diesel demonstrates the wide applicability of this technology.

WFE's electronic control unit regulates the volume of HHO produced to satisfy the requirements and demands of the engine. The ratio of HHO to diesel remains constant, regardless of whether the engine is idling or is navigating a steep incline.

Laboratory results in controlled conditions are a good but often variable indication of the results that are to be expected from this technology in real-road conditions. Yet the desire to further improve the system has led WFE to assess the functionality of *HydroGen*™ under conditions never encountered before; namely on buses in countries where ambient temperatures are different to those in the UK.

*HydroGen*™ electrolysers are autonomous and self-contained, incorporating an in-built water reservoir that requires refilling only every three months. Materials used for the electrolyser plates along with their configuration and surface design, have been developed to maximise oxyhydrogen production with patents pending for both the electrolyser design and the electronic control unit.

*HydroGen*™ operates without the need for engine modification and vehicles can continue to operate without the benefits of the units if the client wishes or if the systems should fail for any reason.

8 S Bari, M Esmaeli, 'Effect of $H_2O_2$ addition in increasing the thermal efficiency of a diesel engine', *Sustainable Energy Centre*, University of South Australia, p.381.

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Splitting water into its constituent parts has generally been used to isolate oxygen from hydrogen by using a membrane. WFE's technology, however, focuses on the unique characteristics of oxyhydrogen when the two gases are held together in a stoichiometric state. Such methods have rarely been explored or incorporated since HHO is unstable and quickly returns to its liquid state (water) or gaseous state (vapour). They therefore exploit a narrow window of opportunity during which oxyhydrogen can be utilised. To achieve this, *HydroGen™* produces HHO on-board the vehicle in quantities defined by the engine. Such a method requires careful and accurate management of the gas, which is achieved through an electronic management system that manufactures and delivers a constant ratio of HHO to diesel (or any carbon based fuel) into the engine.

## 3. Assumptions

The chemical impact of burning fuels in HHO is well documented in the academic papers referenced in this report. For example, Ali Can Yilmaz. Et al. state that the introduction of HHO into internal combustion engines "increases the hydrocarbon ratio of the entire fuel"; it "makes the combustible mixture better premixed with air and more uniform", and "it could also reduce the combustion duration due to hydrogen's high speed of flame propagation in relation to other fuels" [9]

We have highlighted the fuel savings that can be achieved and the reductions in particulates that can be expected in the real world.

Engineers at Sofia Technical University also give us the confidence to assume that CO levels can be significantly reduced.

*'At small engine loads carbon monoxide emissions are lowered by up to 29 % when running the engine with standard diesel fuel as compared to running the engine on a gas-diesel cycle with a volumetric flow rate of OHGM – QHHO = 100 l/min.'* [8]

It can be assumed that by combusting diesel in HHO the fuel can be converted more efficiently into kinetic energy with fewer particulate emissions and lower levels of GHG emissions.

As more energy is released from the carbon fuel, it can reasonably be assumed that less fuel is required by the engine to perform the same or equivalent task. Bus drivers that are sensitive to the performance of their vehicle can ease up on the throttle and maintain the same energy output. Fuel savings are the natural consequence.

If the *HydroGen™* can deliver 67 times more gas (for the amount same current) than the research outlined above by Patil et al, it can be assumed that the impact upon fuel savings and emissions reductions will also be increased (though not necessarily in proportion).

Within Euro 6 vehicles (or BSVI vehicles when they are launched in India in 2020), it can further be assumed that the impact upon DPFs will be positive. If we successfully remove 80% of emissions at the combustion stage, DPFs only have to cope with the residual 20% of

[9]

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emissions that remain post-combustion, with the clear implication that the filters will last longer, perform better and require cleaning and 'regeneration' less often. This project applied to older vehicles without DPFs, so this assumption was not tested.

The robustness of the testing processes was assured by following Indian emissions monitoring regulations, (Rule 115/2 0f Central Motor Vehicle Rules 1989) and by the analysis undertaken by assessors officially authorised by Government of Telangana's Transport department. As highlighted in the emissions certificates (Appendix 1), the tests were conducted three times with opacity cross checked against the k value. This independent testing was undertaken by the assessor at the bus company's depot with engineers from TSRTC and WFE in attendance.

The fuel efficiency was to be monitored independently – and would therefore be equally robust – by ensuring the manual data on fuelling was recorded by TSRTC. Mileage was to be cross referenced by data from Zop-Hop telematics. As a result we were able to better understand and explain the fuel data when it was presented by TSRTC.

## 4. Technology and Equipment

The following technology and equipment was used:

Conventional diesel vehicles: Six Ashok Leyland 6-Wheeler Buses

WFE's HydroGen™ electrolysers model 5.1; 12V and 12A; Two electrolysers per vehicle

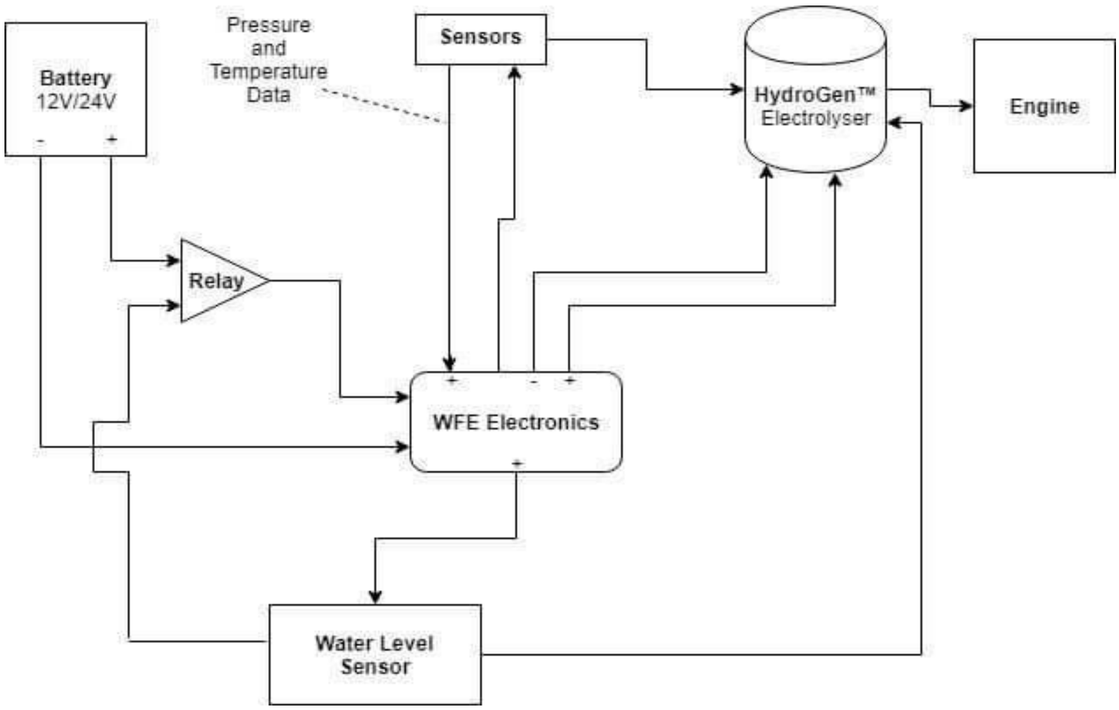


**Figure 5:** WFE electronic control unit



**Figure 5**: GPS Tracking Device: Bharat 101/AIS 140 – provided by Mumbai-based 'Zop-Hop'


**Figure 6:** Emissions testing equipment: Smoke Meter Model SM 05; Acceleration tests provided by Mars Technologies Inc

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# 5. Methodology

## 5.1 Electrolyser installation

The *HydroGen™* units were fitted to six Ashok Leyland diesel buses according to WFE's standard procedures, connecting the gas outlet to the air intake ahead of the turbo. Installations took place in November 2018 following the delivery of the consignment by DHL. The aim was to run the systems for three full months from 1st December 2018 through to 28th February 2019 so that the units could be evaluated by TSRTC and their engineers, drivers and management. Although not the hottest summer months in India, the relatively high temperatures, monsoons, dust and humidity were all expected to have an impact upon the units and subjecting them to these factors was part of the evaluation.

After initially checking the units, it was decided to install two electroysers per vehicle to address the risk of malfunction that may be caused by overheating. The two units operated interchangeably for periods of 2 hours each, giving the units the opportunity to cool. The ECU controlled the interchange and was designed to operate without interruption to gas supply.

A 24v vehicle battery provided the power supply which was fed, via the GPS tracking device, (Bharat 101/AIS 140) to the ECU and the electrolyser unit.

Zop-Hop, an Indian company with strong connections to the transport industry, installed the GPS telemetry.

## 5.2 Testing: emissions

The tests were conducted according to Indian Regulations: Rule 115(2) of Central Motor Vehicle Rules (1989) and conducted by an inspection team authorized by the Transport Department of the State of Telangana. As in the UK, the standardisation of the testing procedure ensures that the data is meaningful. Whilst we had no ability to assess the accuracy or condition of the equipment (nor indeed would this have been appropriate), we did ensure that all testing was conducted by the same inspector using the same equipment so that any shortcomings in the calibration of the machinery or its accuracy, would be minimised.

Testing took place in dry conditions and away from direct sunlight at the TSRTC 'Picket Depot' in Hyderabad. This testing, held in the presence of TSRTC engineers, ensured complete transparency.

The equipment used was the Smoke Meter Model SM 05 provided by Mars Technologies Inc. In accordance with Rulle 115(2), the emission measuring apparatus was connected to the tail pipe of each bus with the temperature of the engine held between 70-75 degrees Celsius, during each of three cycles of testing, between which the system was re-calibrated to avoid contamination.

The engine was kept working at a speed below 2200 rpm, and the emission levels were taken three times per bus to create an average (see certificates; Appendix 1).

The SM05 Meter measured both HSU () and kVal (k Mean Value based upon the industry standard Euclidean algorithm). The HSU is a physical reading of the opacity of the gas being tested and the kVal evaluates the accuracy of the HSU by calculating aberrant readings from clusters taken during the testing process. Ideally the figures should be identical, but a narrow difference demonstrates the validity of both procedures.

### 5.3 Testing: Fuel Usage

TSRTC provided baseline data at the beginning of the trials and it was agreed that the monitoring of fuel consumption would be undertaken by their own technicians in the interests of independence and integrity.

The re-fuelling of buses was recorded at each refill and kilometres travelled recorded. The fuel consumption data during the trial were compared to the consumption figures without the electrolyser.

## 6 Project Limitations

The WFE project team were unsure how the electrolyser would perform in the Indian climate; hence the decision to install two units on each vehicle. The impact of HHO on emissions of $NO_x$ production within the engine was also unclear.

The WFE team were dependent upon Government approved emissions inspections, along with their equipment and processes to undertake the emissions testing. The equipment was rudimentary and unable to deliver detailed analysis of the composition of the emissions produced.

WFE were also dependent upon TSRTC to monitor fuel consumption and vehicle kilometres travelled. In practice, the re-fuelling and monitoring was undertaken manually with the fuel totaled across a whole month. Mileage was taken notionally with bus route distances aggregated to establish a total monthly 'distance'. It was therefore inappropriate for the purposes of obtaining accurate data.

## 7. Results

### 7.1. General

***GPS Tracking****:* The data from the GPS tracking devices was thin and sporadic, offering only basic information about the status of the electrolysers and whether they were "ON" or "OFF" and the distance travelled by each bus. This data was only supplied on a monthly basis and could not therefore be considered a 'live' feed.

This proved to be a frustrating part of the programme as the GPS tracking device had been intended to calibrate the fuel consumption by cross referencing the actual distance travelled by each of the trial buses on a daily basis.

The disparity between the GPS distances and TSRTCs notional distances averaged 3,548 miles per bus per month, rendering fuel consumption data invalid; see below.

***Emissions Monitoring*****:** In India monitoring and emissions testing was undertaken at the depot using mobile emissions laboratories; essentially fully equipped vans which can be operated anywhere, rather than a static MOT-style testing station. The equipment centered on the Smoke Meter Model SM 05, provided by Mars Technologies Inc. and regulated and certified by the

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State Government's road transport authority. This ensured a flexible and reliable analysis programme, with assessments being undertaken with the minimum of 'down-time' for individual bus passenger services.

***Response from TSRTC:*** Whilst TSRTC were pleased with the emissions reductions they expressed the need to ensure costs of the systems were covered by fuel savings; savings which they claimed had not been generated (See Table 3 below).

Concerns were expressed about the way in which our pipes were connected to the inlet of the engine. This occupied the focus of the managers at the bus depot and became a source of great contention. Due to the high operating temperatures and expansion/contraction of the inlet hose, the risk of debris entering the turbo charger after the filter stage, was an issue they argued. They even claimed at one stage they had had to replace all the turbo chargers on each of the buses, although the inconsistency in this claim surfaced as each person appeared to make a different claim. We acknowledged the issue as a risk in principle and agreed to mitigate this risk by creating dedicated 'T' connections on future installations. We have to say there was no evidence for the risk having materialised although it was clear that the senior manager was exploring the potential to be paid for damage which he said had occurred. There was no impact upon the project, but it served to further undermine the trust between us.

### 7.2 Condition of electrolysers

The condition of the electrolysers suggested they had all been through extreme conditions of humidity and dust. One of the buses that was checked (AP 29Z 3290), was not working. The water reservoir was full but the electrolyser was empty. It appeared the valve had leaked. The GPS tracker consistently indicated that the system was active. However, this information was based upon electrical supply and not gas production. A second system had also malfunctioned during the trials and this was reflected in the aberrant readings (vehicle: AP 20Z 0067). Whilst this was disappointing, both parties agreed this to be a positive outcome in that it demonstrated the way in which vehicles would continue to operate normally, if the HydroGen™ system were to fail. It also demonstrated the way in which HydroGen™ systems were (mostly) robust enough to withstand extreme weather conditions prevalent in India.

### 7.3 Emissions results

In the initial plans for conducting emissions tests, TSRTC were to collect baseline readings prior to the installation of the *HydroGen*™ units. However, such tests were not carried out due to organisational issues within TSRTC. It became necessary for the baseline tests to be undertaken a day after the *HydroGen*™ units had functioned on each vehicle for a day. Table 3 presents the results of the tests in the column headed 'HydroGen.' The testing with ours systems was undertaken on 28$^{th}$ November with the electrolysers still being installed and functional at the point that we fitted and trialled the electrolysers. Having removed the units between 9 to 12 March, the vehicles were re-tested on 13$^{th}$ March to indicate the contrasts between emissions with our system and emissions without our system.

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**Table 3:** Emissions Results Summary

| Vehicle Registration | kVal | | % Difference | Hsu | | % Difference |
|---|---|---|---|---|---|---|
| | 28/11/18 | 13/03/19 | | 28/11/18 | 13/03/19 | |
| | **HydroGen** | **HydroGen removed** | | **HydroGen** | **HydroGen removed** | |
| AP20 Z 0067 | 0.24 | 0.32 | 25% | 9.81 | 12.83 | 23.5% |
| AP29 Z 964 | 0.12 | - | - | 5.03 | - | |
| AP29 Z 2255 | 0.1 | 0.6 | 83.4% | 4.21 | 22.74 | 81.5% |
| AP20 Z 0071 | 0.28 | 0.83 | 66.5% | 11.34 | 30.02 | 62.3% |
| AP29 Z 3290 | 0.19 | 0.63 | 69.8% | 7.85 | 23.75 | 66.9% |
| AP29 Z 409 | 0.08 | 0.64 | 87.5% | 3.38 | 24.06 | 85.9% |
| Averages of the FOUR | 0.19 | 0.68 | 76.8% | 6.7 | 25.14 | 74.15% |

The system on Bus AP29 Z 964 failed during the trial due to a faulty valve and so there was no meaningful data.

The re-testing of AP20 Z 0067 was the first vehicle to be re-tested and due to scheduling issues was hurriedly tested before conditions could be standardised and equipment calibrated. It was agreed these were therefore invalid.

The HSU (Hartridge Smoke Units) reflect an average opacity improvement of 74.1%, from the four valid data sets, which is in line with previous expectations of approximately 80%. The kVal figures are an indirect cross-reference based upon a Euclidean algorithm creating mean readings of the emissions. The average improvement of the four units is 76.8%, which is a 2.7% difference to the HSU readings. In both cases only the overall emissions measured by smoke levels is measured, with a combined average of 75.4%. No individual data was available for CO, $CO_2$, $NO_x$ or particulate matter. Attempts were made to make arrangements for Dave Miller from 3DATX to bring his sophisticated monitoring systems to India to deliver emissions profiles rather than simple 'opacity' readings. Dave had been introduced to us by the Stockholm Environment Institute and during the project we had a fruitful meeting with him in Berlin, when he came to Europe to visit clients. Unfortunately it was not possible for Dave to come to India in the time frame we had, but the project has convinced us of the need for greater detail in evaluating the types of emissions we are reducing and indeed the profile of the emissions that remain.

## 7.4 Fuel consumption results

The figures provided by TSRTC were at odds with what the science expected us to believe and indeed what our own experiences in the UK had demonstrated. More remarkable was the apparent average difference of just 0.4% (see Table 4).

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**Fuel Efficiency Report – 22nd March 2019**
**KM/Ltr**
**Name of HVT Program:** Transport-Technology Research Innovation for International Development (T-TRIID)-July2018
**Project Title:** LC016 -Low Carbon Hyderabad Bus Fleets
**Key Contact of Grant Recipient:** Phil Davies, Tel:07802567228, e-mail: p.davies@waterfuelengineering.com
**Company Name of Grant Recipient:** Water Fuel Engineering Ltd.

| | Reg plate | JUL | AUG | Sept | Oct | Nov | **Average Jul-Nov** | Dec | Jan-19 | Feb (17/02/19 | UP to Feb 19 | **Average Dec-Feb** | **Diefference** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20Z0067 | 4.93 | 4.80 | 4.94 | 4.89 | 5.10 | **4.93** | 5.04 | 5.00 | 5.14 | 4.97 | **5.04** | **2%** |
| 2 | 29Z409 | 5.30 | 5.42 | 5.44 | 5.49 | 5.55 | **5.44** | 5.50 | 5.34 | 5.72 | 5.51 | **5.52** | **1%** |
| 3 | 20Z0071 | 5.44 | 5.36 | 5.44 | 5.36 | 5.16 | **5.35** | 5.24 | 5.26 | 5.51 | 5.30 | **5.33** | **0%** |
| 4 | 29Z964 | 5.06 | 5.02 | 5.08 | 4.90 | 5.05 | **5.02** | 4.90 | 5.07 | 5.15 | 5.04 | **5.04** | **0%** |
| 5 | 29Z3290 | 5.77 | 5.18 | 5.43 | 5.28 | 5.12 | **5.36** | 5.26 | 5.28 | 5.77 | 5.30 | **5.40** | **1%** |
| 6 | 29Z2255 | 5.18 | 5.23 | 5.06 | 5.11 | 5.03 | **5.12** | 4.96 | 5.02 | 4.96 | 5.11 | **5.01** | **-2%** |
| | Average | 5.28 | 5.17 | 5.23 | 5.17 | 5.17 | **5.20** | 5.15 | 5.16 | 5.38 | 5.21 | **5.22** | **0.35%** |

**Table 4:** Fuel Efficiency Report

However, when we cross-referenced the distances covered in the TSRTC report against the GPS distances covered by Zop-Hop technologies; the four buses in our final analysis showed an average discrepancy of 3548 km (see Table 5).

**Distance Report – 22nd March 2019**
**in KM**
**Name of HVT Program:** Transport-Technology Research Innovation for International Development (T-TRIID)-July2018
**Project Title:** LC016 -Low Carbon Hyderabad Bus Fleets
**Key Contact of Grant Recipient:** Phil Davies, Tel:07802567228, e-mail: p.davies@waterfuelengineering.com
**Company Name of Grant Recipient:** Water Fuel Engineering Ltd.

| | Reg plate | JULY | AUGUST | September | October | November | **Average Jul-Nov** | December | Jan-19 | Feb | **Average Dec-Feb** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20Z0067 | 11070 | 12982 | 11862 | 11250 | 11184 | **11670** | 7744 | 10574 | 7548 | **8622** |
| 2 | 29Z409 | 9706 | 8696 | 8926 | 9440 | 7852 | **8924** | 10355 | 8647 | 7683 | **8895** |
| 3 | 20Z0071 | 10440 | 8280 | 8640 | 9170 | 10080 | **9322** | 8050 | 8680 | 9108 | **8613** |
| 4 | 29Z964 | 9600 | 7960 | 6360 | 5040 | 6840 | **7160** | 9720 | 9720 | 7160 | **8867** |
| 5 | 29Z3290 | 840 | 7980 | 10459 | 9920 | | **7300** | | | | |
| 6 | 29Z2255 | 10560 | 9614 | 3000 | 10680 | | **8464** | | | | |
| | Average | 8703 | 9252 | 8208 | 9250 | 8989 | **8806** | **8967** | **9405** | **7875** | **8749** |

| **GPS Distance Recorded Jan** | | **TSRTC Jan-19** | **Diefference** |
|---|---|---|---|
| AP20Z0067 | 7238 | 10574 | **31.54%** |
| AP29Z409 | 3794 | 8647 | **56.13%** |
| AP20Z0071 | 5452 | 8680 | **37.19%** |
| AP29Z964 | 6942 | 9720 | **28.58%** |
| AP29Z3290 | 6495 | | |
| AP29Z2255 | 7293 | | |

**Table 5:** KM covered by vehicles. TSRTC data vs GPS data

It was revealed that TSRTC distance data is ‘notional’ rather than actual, based upon pre-determined bus routes. This has proved very frustrating and indicates either a lack of robustness on the part of the Authorities there, or worse, an active culture of building margins into figures for personal gain. These concerns have been raised with DFID and WFE are actively seeking support, advice and guidance on identifying potential areas of corruption. WFE have become the very first signatories to the UK Government's Anti-Bribery and Anti-Corruption programme.

### 7.5 Commercial results

During the test period we have actively engaged with potential agents/investors/partners in India and further afield.

TSRTC have agreed in principle to purchase 8,600 units from us if we can deliver fuel savings of >10% with a price point that falls within their fuel savings range.

In India, we secured a Letter of Intent from Tavasya Venture (see Appendix 2), a development company which has expressed interest in helping us to establish a manufacturing base in Hyderabad and investing in WFE.

In Sri Lanka, we have met with Compass Technologies who again have expressed an interest in collaborating with us on the exploitation of our technology from Colombo. The Chief Executive has already made approaches to the Sri Lankan Government (see Appendix 3)

In Jordan, Mazen Electrical Industries have similarly expressed an interest in collaborating to help us to expand in the Middle-East. We have held a meeting in Amman with the owner, Haddadin Mazen and we have been sharing our research with Mahmoud Al-Ansari of Al-Wafra Industrial Co Ltd. Mahmoud has made some steps in developing a home heating system using HHO and we hope to be able to collaborate with him as we combine his areas of interest with our experience. (see Appendix 4)

We have secured an agreement to work with 3DATX on the development of more robust monitoring systems including a micro portable emissions system that can be fitted to EACH vehicle for permanent emissions monitoring.

Although we were disappointed with the Zop-Hop telematics, we hope to pursue our collaboration with them and hope that they too will use this experience to improve their systems.

## 8. Lessons learned

A number of lessons can be learned as a result of our experiences in India, covering communications issues, cultural challenges, the integrity of data and data gathering, and of course, challenges within our own systems where flaws were identified and improvements diagnosed.

We needed to adopt a more structured approach to transportation of equipment across international borders, to India and elsewhere, through establishing a better infrastructure, aimed at faster and more efficient distribution of materials and equipment on a global scale.

We need to ensure greater clarity within contracts defining explicit details of vehicles being fitted, possibly with penalty clauses to cover additional costs if changes to the agreement are made. We were guilty of assuming that what we were told could be taken as read. This was rarely the case, with vehicles being changed at the last minute and access times to vehicles being denied at the very times we were due to start.

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Overall, we need to allow more time for things to go wrong. Upon planning we need to account for wider time margins, giving us the opportunity for a better response to potential problems.

*Partnership working and cultural challenges*: The experience of dealing with TSRTC, Zop-Hop and even Elico, suggests that there may be a culture in India of 'no response'. Phone calls and emails remained unanswered for extended periods and we repeatedly heard the phrase "To do business in India you have to be in India". Face-to-face meetings seemed to be the preferred way of communicating. For example, even though TSRTC had voluminous data relating to fuel savings since the start of the trial, six separate requests for feedback on this data were met with silence. It was only when we arrived in March to complete the trials that we could access the manual data, which was clearly flawed, as outlined above.

*Customs*: The transfer of commodities across borders needs greater attention at the early stage to ensure that customs clearance can be achieved more effectively.

*Constant monitoring*: It was agreed that the programme needed a dedicated WFE engineer on hand throughout the trial, in order to provide better data validation and quick response in case of system malfunction.

*Real-Time Emissions Monitoring:* We are at an early stage of discussions with 3DATX, in which we are exploring the possibility of having tail pipe exhaust monitoring on each vehicle to evaluate gases in real time.

*Water supply*: top-ups should be recorded and monitored tightly to help address any system failures. A total of 120 litres of water was used but there is no indication as to which systems used how much.

*Driver habits*: It is important to use the same drivers and the same vehicles when monitoring on future occasions to mitigate the impact of driver habits.

*Valves*: The new design of the latest version of the electrolyser will avoid the need for valves as water will be introduced into the system from the reservoir directly.

*Interface with the engine system*: The need for a pre-formed connection is acknowledged so that there is no weakening of the pipework at the air intake.

## 9. Application to the national transport system

With the concept proven, it is reasonable to believe that scaling up the programme to a national level will be achievable within in a realistic timescale. The environmental benefits are proportional to the number of units in operation. Every hybrid bus will contribute measurable differences of 76.4 per cent reduction in pollutant emissions, whilst the collective impact, of 10,000 for example, would be life-changing to the residents of the region. Further upgrades to the system as a result of these trials would seek to increase this figure. Scaled up to cover the national transport system the results would be proportionate to the number of vehicles upgraded,

Such vehicles would also be used for longer as engine efficiency is increased when *HydroGen™* is installed. The result would deliver a more efficient use of resources such as

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fuel and older vehicles, along with reducing the necessity to manufacture new vehicles to reach short-term environmental standards.

## 10. Discussion

Thanks to the T-TRIID grant, WFE has been able to successfully complete road trials in India in collaboration with the TSRTC. The retrofitting of HHO electrolysers to six buses, aimed to demonstrate the ways in which this technology can reduce emissions on older, conventional diesel vehicles. In LICs alternative fuels and fleet upgrades are unaffordable and, (as developed countries are finding), ineffective and unsuitable for heavy vehicles.

The project exposed WFE to the challenges of exporting, customs clearance, excise duties and documentation. The geography (working 5,000 miles from our base), climate (working in temperatures of up to 35C), culture (working with partners of a different mind-set), each added to the challenges. However, WFE staff were enriched and empowered by the experience, rendering the company as a whole, better equipped to take this project to the next stage.

Although the project was conducted exclusively in Telangana State, WFE were mindful of DFIDs objectives to reach out to all LICs in the pursuit of improved air quality. Consequently, partners across India have been identified and collaborations in Jordan and Sri Lanka have also commenced in principle. As this report will demonstrate, scaling up to reach out to all LICs is entirely possible.

The project in Telangana has attracted the support of Indian investment company, Tavasya Venture; with the promise of investment and support. Initial discussions with their Head of Business Development has resulted in a Letter of Intent.

The momentum generated by this project and the support received from T-TRIID (and from Gary Haq in particular), has enabled WFE to both deliver on and exceed expectations as laid out in the DFID guidelines.

Moreover, the results of the trials themselves have validated the theories behind the technology and established the effectiveness of retrofit electrolysers in matching emissions in the laboratory (80%), with emissions reductions in real-world conditions (75.4%), as measured by the standard equipment currently available.

Although two of the units malfunctioned, the lessons learned will enable further improvements to be made to the systems. Challenges due to the extreme weather conditions in India had been anticipated, however the trial revealed several additional weaknesses in the systems that can now be corrected; modifications that will deliver reliable, market-ready units for countries throughout the world.

The four units that completed the trials delivered consistent emissions reductions averaging 75.38%; Just 5% below target levels that had been reached in laboratory conditions. The two

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dimensions to the emissions tests (HSU 'opacity' and kVal - 'mean' value calculation), again provided evidence of the integrity of the analysis by delivering comparable data within 3 percentage points of each other. The emissions testing was undertaken independently by a Government of India inspection team and certified accordingly.

Fuel consumption was monitored by TSRTC, who reported no significant savings. Whilst this was disappointing, it is most likely reflected by the anomalies within the TSRTC processes themselves which were manually undertaken and loosely recorded. Variations in driver performance accounted for variations in fuel consumption of 65.1%, so identifying savings of 10% would always be a challenge. However, unlike emissions analysis, fuel efficiencies are easily monitored and verified, and we stand by the results obtained elsewhere which have never fallen below 8% improvement levels.

With emissions results established along with the interest of funding partners in India, the potential for the WFE electrolyser across LICs is immense.

## 11. Way Forward

1. To build upon the relationship with TSRTC and to become part of their overall strategy as they seek to make fuel savings.
2. To develop the electrolyser with version 6.0 capabilities that will avoid the need for valves (valves which failed on one of the units). Research Collaboration to be established with Sheffield Hallam University to evaluate the use of the cheaper 200 series steel to reduce the selling price of the electrolyser.
3. To develop the relationship with Tavasya Venture Foundation; an Investment corporation in Hyderabad who have committed to working with WFE in principle by issuing a Letter of Intent. Tavasya have offered support as progress is made through the validation of the technology in terms of fuel savings, accreditation within the Indian legislature, to manufacture the electrolysers and to market them across Asia.
4. To produce a custom-made inlet connection for the India market which will avoid the risk of 'connector-breach' at the "T" junction between our gas supply pipe and the engine air intake pipe.
5. To upgrade the TSRTC fleet (8600 vehicles) in Telangana to create fuel savings of 10%+ across the board.
6. To improve the electrolysers and to lift the emissions reductions from 75% to 80% and above, across all vehicles.
7. Adapting the UK Telematics system to use an Indian SIM card so it functions there, and to upgrade the system to report on fuel consumption.

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8. Establish locally based technical support for the client base that uses this technology, based in each depot (97 depots with 88 vehicles per depot).
9. Expand the installation programme to all suitable vehicles within Telanaga in collaboration with TSRTC.
10. To replicate this programme across the whole of India.
11. To replicate the programme in LIC countries, initially in Sri Lanka and Jordan.
12. To build upon the relationship we have developed with Sheffield University to assist with the further development of the HydroGen, collaborating with their Low Carbon Combustion Campus.
13. To align ourselves with the UK Government's Anti-Bribery and Anti-Corruption programme. We have become the very first UK exporter to sign up for DFID's programme aimed at helping business navigate their way around the corrupt practices that plague the developing world. Gemma Aiolfi (Basel Institute on Governance) is our mentor and the programme will be completed in time for our return to India in Autumn.

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## Appendices

1. Emissions Certificates (With and without Electrolsyers)
2. Letter of Intent; Tavasya Venture
3. Letter of Support: Compass Synergies; Sri Lanka
4. E-Mail from Al-Wafra Industrial Co updating on progress.

Appendix 1.Emissions Certificates (With and without Electrolsyers)

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## COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

**Serial No.** 24185

**Rule 115(2) Of C.M.V.Rules 1989**

AUTHORISED by Transport Department, Govt. of Telangana

All India Valid

I.D No : D001201815

Vehicle Registration No. : AP29 Z 2255

Year of Registration : 2011

Odometer Reading :

Type of Vehicle: 6 Wheeler

Make: ashok lelyand

Model: bus

Fuel: DIESEL

Date: 28 Nov 2018

Time: 10:09:22 PM

Test Results

| Flush Mean | Flush Idle Rpm | Flush Max Rpm |
|---|---|---|
| | 0743 | 1256 |

| Trial | Idle Rpm | Max Rpm | k Val | Hsu | Oil Temp |
|---|---|---|---|---|---|
| 1 | 0780 | 1280 | 0.20 | 08.24 | 075 |
| 2 | 0750 | 1270 | 0.11 | 04.62 | 075 |
| 3 | 0760 | 1190 | 0.00 | 00.00 | 075 |
| | | Avg | 0.1 | 04.21 | |

Photograph of the Vehicle


Regulation : K-Value is 2.45 1/m (Opacity : 65%)
Certified that this Vehicles K - Mean and HSU % value Confirms to the standards prescribed under Rule 115(2) of CMV Rules 1989.

Validity: 6 Months

Valid Upto: 27 May 2019

Seal of the Test station : M/s Sri Lakshmi Narasimha ... 06/2015

Authorised Signature

Pollution Testing Stations Association Telangana

PREVENT POLLUTION PROTECT ENVIRONMENT, (PTSA - TELANGANA)

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## COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No. 24184

Rule 115(2) Of C.M.V.Rules 1989

AUTHORISED by Transport Department. Govt. of Telangana

All India Valid

I.D No : D001201813
Vehicle Registration No. : AP20 Z 0071
Year of Registration : 2012
Odometer Reading :

Type of Vehicle: 4 Wheeler
Make: ashok lelyand
Model: bus

Fuel: DIESEL
Date: 28 Nov 2018
Time: 6:16:33 PM

Test Result:

| Flush | Flush | Acceleration | | | |
|---|---|---|---|---|---|
| Mean | Min Rpm | Max Rpm | | | |
| | 0806 | 1373 | | | |
| Trial | Min Rpm | Max Rpm | k Val | Hsu | Oil Temp |
| 1 | 0800 | 1250 | 0.74 | 27.25 | 075 |
| 2 | 0800 | 1220 | 0.05 | 02.13 | 075 |
| 3 | 0800 | 1220 | 0.04 | 01.71 | 075 |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 12 | Avg | | 0.28 | 11.34 | |

Regulation : K-Value is 2.45 1/m (Opacity : 65%)
Certified that this Vehicles K - Mean and HSU % value Confirms to the standards prescribed under Rule 115(2) of CMV Rules 1989.

Photograph of the Vehicle


Validity: 6 Months

Valid Upto: 27 May 2019

M/s. Sri Lakshmi ... Lic No: 06/2015

Seal of the Test station : Authorised Signature

Pollution Testing Stations Association Telangana

PREVENT POLLUTION PROTECT ENVIRONMENT, (PTSA - TELANGANA)

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## COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No. 24187

Rule 115(2) Of C.M.V.Rules 1989

AUTHORISED by Transport Department, Govt. of Telangana

All India Valid

I.D No : D001201814
Vehicle Registration.No. : AP29 Z 3290
Year of Registration : 2012
Odometor Reading :

Type of Vehicle: 6 Wheeler
Make: ashok lelyand
Model: bus

Fuel: DIESEL
Date: 28 Nov 2018
Time: 6:39:22 PM

Test Result: Flush Free Acceleration

| Mean | Idle Rpm | Max Rpm |
|---|---|---|
| | 0803 | 1286 |

| Trial | Idle Rpm | Max Rpm | k Val | Hsu | Oil Temp |
|---|---|---|---|---|---|
| 1 | 0830 | 1300 | 0.42 | 16.52 | 071 |
| 2 | 0800 | 1280 | 0.06 | 02.55 | 071 |
| 3 | 0800 | 1310 | 0.08 | 03.38 | 071 |
| 4 | | | | | |
| | | | | | |
| | | Avg | 0.19 | 07.85 | |

Regulation : K-Value is 2.45 1/m (Opacity : 65%)
Certified that this Vehicles K - Mean and HSU % value Confirms to the standards prescribed under Rule 115(2) of CMV Rules 1989.

Photograph of the Vehicle


Validity: 6 Months

Valid Upto: 27 May 2019

Seal of the Test station : M/S. Sri Lakshmi ... Lic No: 08/20..

Authorised Signature

Pollution Testing Stations Association Telangana

PREVENT POLLUTION PROTECT ENVIRONMENT, (PTSA - TELANGANA)

COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No. 24188

Rule 115(2) Of C.M.V.Rules 1989

AUTHORISED by Transport Department, Govt. of Telangana

All India Valid

I.D No : D001201816

Vehicle Registration.No. : AP29 Z 409

Year of Registration : 2011

Odometor Reading:

Type of Vehicle: 6 Wheeler

Make: ashok lelyand

Model: bus

Fuel: DIESEL

Date: 28 Nov 2018

Time: 10:20:06 PM

Photograph of the Vehicle


Test Results Free Acceleration

| Flush Mean | Flush Idle Rpm | Max Rpm | | | |
|---|---|---|---|---|---|
| | 0820 | 1346 | | | |
| **Trial** | **Idle Rpm** | **Max Rpm** | **k Val** | **Hsu** | **Oil Temp** |
| 1 | 0780 | 1290 | 0.19 | 07.85 | 075 |
| 2 | 0770 | 1550 | 0.02 | 00.86 | 075 |
| 3 | 0770 | 1140 | 0.02 | 00.86 | 075 |
| - | - | Avg | 0.08 | 03.38 | - |

RESULT : PASSED

Regulation : K-Value is 2.45 1/m (Opacity : 65%)
Certified that this Vehicles K - Mean and HSU % value Confirms to the standards prescribed under Rule 115(2) of CMV Rules 1989.

Validity: 6 Months

Valid Upto: 27 May 2019

Pollution Testing Stations Association Telangana

Seal of the Test station : M/s. Sri Lakshmi Narasimha MPTS Lic No: 06/2

Authorised Signature

PREVENT POLLUTION PROTECT ENVIRONMENT, (PTSA - TELANGANA)

**Water Fuel Engineering**

407 Britannia House, 1-11 Glenthorne,
London, W6 0LH, E-mail:
office@waterfuelengineering.com,
Tel./Fax: +44(0)1226 213 314,
www.waterrfuelengineering.com


## COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No. 24189

Rule 115(2) Of C.M.V.Rules 1989

AUTHORISED by Transport Department, Govt. of Telangana

All India Valid

I.D No :
Vehicle Registration.No: D001201818
Year of Registration : AP20 Z 0067
Odometor Reading: 2012

Type of Vehicle: 6 Wheeler
Make: ashok lelyand
Model: bus

Fuel: DIESEL
Date: 28 Nov 2018
Time: 11:53:41 PM

Test Results

| Flushs | Flushed Acceleration | |
|---|---|---|
| Mean | Idle Rpm | Max Rpm |
| | 0856 | 2060 |

| Trial | Idle Rpm | Max Rpm | k Val | Hsu | Oil Temp |
|---|---|---|---|---|---|
| 1 | 0890 | 1800 | 0.04 | 01.71 | 071 |
| 2 | 0810 | 1890 | 0.00 | 00.00 | 071 |
| 3 | 0920 | 1910 | 0.67 | 25.03 | 071 |
| | | Avg | 0.24 | 09.81 | |

Regulation : K-Value is 2.45 1/m (Opacity : 65%)
Certified that this Vehicles K - Mean and HSU % value Confirms to the standards prescribed under Rule 115(2) of CMV Rules 1989.

RESULT : PASSED

Photograph of the Vehicle


Validity: 6 Months

Valid Upto: 27 May 2019

Seal of the Test Station : M/s. Sri Lakshmi Narasimha MPTS

Authorised Signature

Pollution Testing Stations Association Telangana

PREVENT POLLUTION PROTECT ENVIRONMENT, (PTSA - TELANGANA)

**Water Fuel Engineering**

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London, W6 0LH, E-mail:
office@waterfuelengineering.com,
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www.waterrfuelengineering.com

COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No. 24191

Rule 115(2) Of C.M.V.Rules 1989

AUTHORISED by Transport Department, Govt. of Telangana

All India Valid

I.D No :
Vehicle Registration.No. : D001201817
Year of Registration : AP29 Z 964
Odometor Reading: 2011

Type of Vehicle: 6 Wheeler
Make: ashok lelyand
Model: bus

Fuel: DIESEL
Date: 28 Nov 2018
Time: 10:45:59 PM

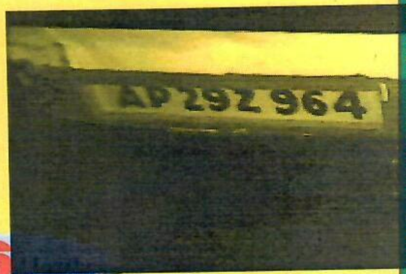
Test Result: Free Acceleration

| Flush Mean | Flush Idle Rpm | Max Rpm | | | |
|---|---|---|---|---|---|
| | 0836 | 1350 | | | |
| Trial | Idle Rpm | Max Rpm | k Val | Hsu | Oil Temp |
| 1 | 0810 | 1460 | 0.25 | 10.19 | 075 |
| 2 | 0840 | 1280 | 0.08 | 03.38 | 075 |
| 3 | 0820 | 1280 | 0.04 | 01.71 | 075 |
| - | - | Avg | 0.12 | 05.03 | |

RESULT - PASSED

Regulation : K-Value is 2.45 1/m (Opacity : 65%)
Certified that this vehicles K - Mean and HSU % value Confirms to the standards prescribed under Rule 115(2) of CMV Rules 1989.

Photograph of the Vehicle




Validity: 6 Months

Valid Upto: 27 May 2019

M/s. Sri ...
Lic No: ...

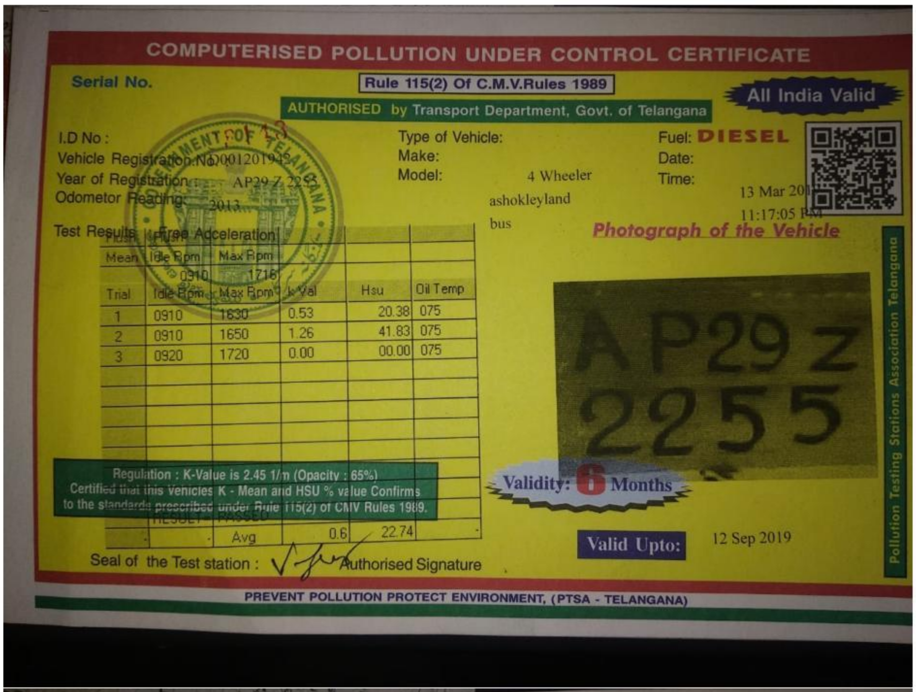
Seal of the Test station :

Authorised Signature

Pollution Testing Stations Association Telangana

PREVENT POLLUTION PROTECT ENVIRONMENT, (PTSA - TELANGANA)

407 Britannia House, 1-11 Glenthorne,
London, W6 0LH, E-mail:
office@waterfuelengineering.com,
Tel./Fax: +44(0)1226 213 314,
www.waterrfuelengineering.com



COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No.

Rule 115(2) Of C.M.V.Rules 1989

AUTHORISED by Transport Department, Govt. of Telangana

All India Valid

I.D No :
Vehicle Registration.No: 0001201943
Year of Registration : AP29 Z 2255
Odometor Reading: 2013

Type of Vehicle: 4 Wheeler
Make: ashokleyland
Model: bus

Fuel: DIESEL
Date: 13 Mar 20
Time: 11:17:05 PM

Test Results : Free Acceleration

| Mean | Idle Rpm | Max Rpm | | | |
|---|---|---|---|---|---|
| | 0910 | 1716 | | | |
| **Trial** | **Idle Rpm** | **Max Rpm** | **k Val** | **Hsu** | **Oil Temp** |
| 1 | 0910 | 1630 | 0.53 | 20.38 | 075 |
| 2 | 0910 | 1650 | 1.26 | 41.83 | 075 |
| 3 | 0920 | 1720 | 0.00 | 00.00 | 075 |
| | RESULT = PASSED | | | | |
| | | Avg | 0.6 | 22.74 | |

Regulation : K-Value is 2.45 1/m (Opacity : 65%)
Certified that this Vehicles K - Mean and HSU % value Confirms to the standards prescribed under Rule 115(2) of CMV Rules 1989.

Photograph of the Vehicle

AP29 Z
2255

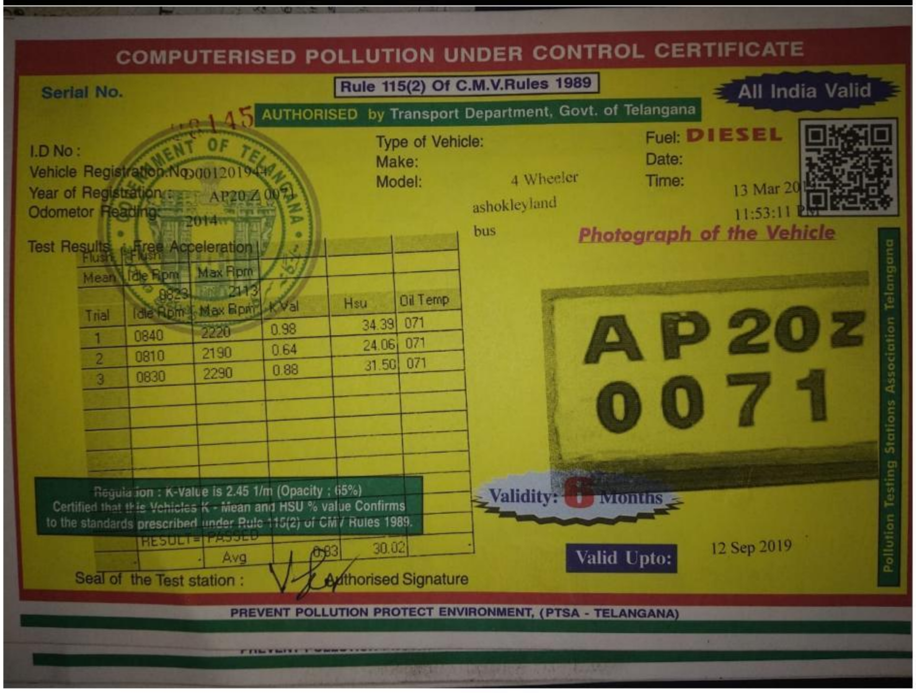
Validity: 6 Months

Valid Upto: 12 Sep 2019

Seal of the Test station : Authorised Signature

Pollution Testing Stations Association Telangana

PREVENT POLLUTION PROTECT ENVIRONMENT, (PTSA - TELANGANA)



COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No.

Rule 115(2) Of C.M.V.Rules 1989

AUTHORISED by Transport Department, Govt. of Telangana

All India Valid

I.D No :
Vehicle Registration.No: 0001201944
Year of Registration : AP20 Z 0071
Odometor Reading: 2014

Type of Vehicle: 4 Wheeler
Make: ashokleyland
Model: bus

Fuel: DIESEL
Date: 13 Mar 20
Time: 11:53:11 PM

Test Results : Free Acceleration

| Mean | Idle Rpm | Max Rpm | | | |
|---|---|---|---|---|---|
| | 0823 | 2113 | | | |
| **Trial** | **Idle Rpm** | **Max Rpm** | **K Val** | **Hsu** | **Oil Temp** |
| 1 | 0840 | 2220 | 0.98 | 34.39 | 071 |
| 2 | 0810 | 2190 | 0.64 | 24.06 | 071 |
| 3 | 0830 | 2290 | 0.88 | 31.50 | 071 |
| | RESULT = PASSED | | | | |
| | | Avg | 0.83 | 30.02 | |

Regulation : K-Value is 2.45 1/m (Opacity : 65%)
Certified that this Vehicles K - Mean and HSU % value Confirms to the standards prescribed under Rule 115(2) of CMV Rules 1989.

Photograph of the Vehicle

AP20z
0071

Validity: 6 Months

Valid Upto: 12 Sep 2019

Seal of the Test station : Authorised Signature

Pollution Testing Stations Association Telangana

PREVENT POLLUTION PROTECT ENVIRONMENT, (PTSA - TELANGANA)

407 Britannia House, 1-11 Glenthorne,
London, W6 0LH, E-mail:
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Tel./Fax: +44(0)1226 213 314,
www.waterrfuelengineering.com

COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No.

Rule 115(2) Of C.M.V.Rules 1989

AUTHORISED by Transport Department, Govt. of Telangana

All India Valid

I.D No :
Vehicle Registration No: D001201933
Year of Registration : AP29 Z 3290
Odometer Reading: 2014

Type of Vehicle: 4 Wheeler
Make: ashokleyland
Model: bus

Fuel: DIESEL
Date: 13 Mar 20
Time: 11:34:47

Test Results : Free Acceleration

| Mean | Idle Rpm | Max Rpm | | | |
|---|---|---|---|---|---|
| | 0806 | 1843 | | | |
| Trial | Idle Rpm | Max Rpm | K Val | Hsu | Oil Temp |
| 1 | 0770 | 1620 | 0.83 | 30.02 | 071 |
| 2 | 0800 | 2030 | 0.75 | 27.57 | 071 |
| 3 | 0800 | 1860 | 0.32 | 12.86 | 071 |
| | | Avg | 0.63 | 23.73 | |

RESULT= PASSED

Regulation : K-Value is 2.45 1/m (Opacity : 65%)
Certified that this Vehicles K - Mean and HSU % value Confirms to the standards prescribed under Rule 115(2) of CMV Rules 1989.

Photograph of the Vehicle

AP29 3290

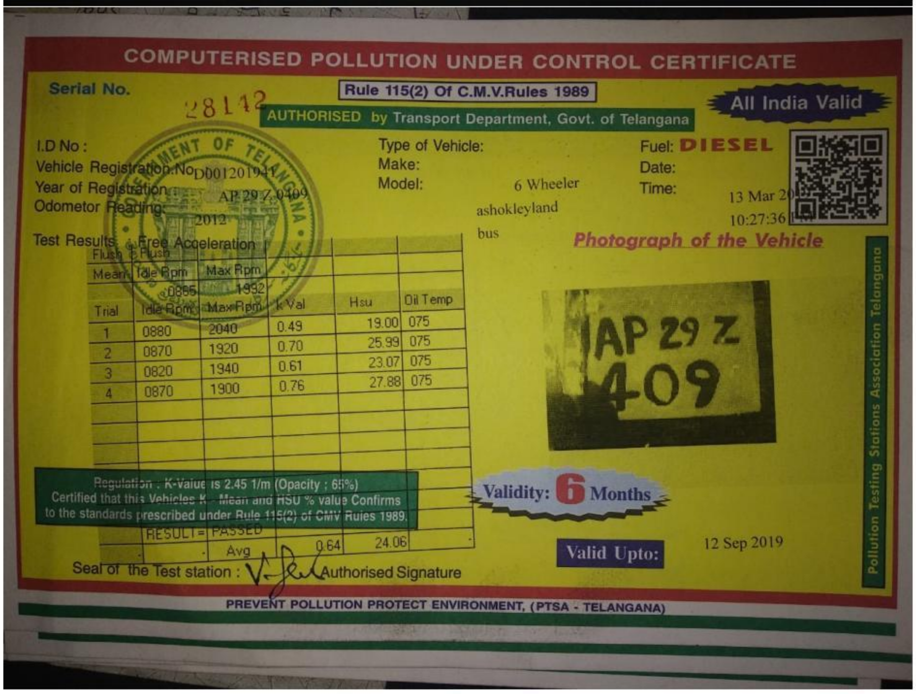
Validity: 6 Months

Valid Upto: 12 Sep 2019

Seal of the Test station : Authorised Signature

Pollution Testing Stations Association Telangana

PREVENT POLLUTION PROTECT ENVIRONMENT, (PTSA - TELANGANA)



COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No. 28142

Rule 115(2) Of C.M.V.Rules 1989

AUTHORISED by Transport Department, Govt. of Telangana

All India Valid

I.D No :
Vehicle Registration No: D001201941
Year of Registration : AP 29 Z 0409
Odometer Reading: 2012

Type of Vehicle: 6 Wheeler
Make: ashokleyland
Model: bus

Fuel: DIESEL
Date: 13 Mar 20
Time: 10:27:36

Test Results : Free Acceleration

| Mean | Idle Rpm | Max Rpm | | | |
|---|---|---|---|---|---|
| | 0865 | 1932 | | | |
| Trial | Idle Rpm | Max Rpm | K Val | Hsu | Oil Temp |
| 1 | 0880 | 2040 | 0.49 | 19.00 | 075 |
| 2 | 0870 | 1920 | 0.70 | 25.99 | 075 |
| 3 | 0820 | 1940 | 0.61 | 23.07 | 075 |
| 4 | 0870 | 1900 | 0.76 | 27.88 | 075 |
| | | Avg | 0.64 | 24.06 | |

RESULT= PASSED

Regulation : K-Value is 2.45 1/m (Opacity : 65%)
Certified that this Vehicles K - Mean and HSU % value Confirms to the standards prescribed under Rule 115(2) of CMV Rules 1989.

Photograph of the Vehicle

AP 29 Z 409

Validity: 6 Months

Valid Upto: 12 Sep 2019

Seal of the Test station : Authorised Signature

Pollution Testing Stations Association Telangana

PREVENT POLLUTION PROTECT ENVIRONMENT, (PTSA - TELANGANA)

COMPUTERISED POLLUTION UNDER CONTROL CERTIFICATE

Serial No. 28149

Rule 115(2) Of C.M.V.Rules 1989

AUTHORISED by Transport Department, Govt. of Telangana

All India Valid

I.D No : D001201945
Vehicle Registration No : AP 20 Z 0067
Year of Registration : 2014
Odometor Reading:

Type of Vehicle: 4 Wheeler
Make: ashokleyland
Model: bus

Fuel: DIESEL
Date: 14 Mar 20
Time: 12:33:36

Test Results : Free Acceleration

| | | |
|---|---|---|
| Flush | Flush | |
| Mean | Idle Rpm | Max Rpm |
| | 0756 | 1713 |

| Trial | Idle Rpm | Max Rpm | k Val | Hsu | Oil Temp |
|---|---|---|---|---|---|
| 1 | 0750 | 1630 | 0.92 | 32.67 | 070 |
| 2 | 0730 | 1730 | 0.00 | 00.00 | 070 |
| 3 | 0730 | 1750 | 0.04 | 01.71 | 070 |
| | RESULT= | PASSED | | | |
| | | Avg | 0.32 | 12.86 | |

Regulation : K Value is 2.45 1/m (Opacity ; 65%)
Certified that this Vehicles K - Mean and HSU % value Confirms to the standards prescribed under Rule 115(2) of CMV Rules 1989.

Photograph of the Vehicle

AP20Z 0067

Validity: 6 Months

Valid Upto: 13 Sep 2019

Seal of the Test station : Authorised Signature

Pollution Testing Stations Association Telangana

PREVENT POLLUTION PROTECT ENVIRONMENT, (PTSA - TELANGANA)

407 Britannia House, 1-11 Glenthorne,
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Tel./Fax: +44(0)1226 213 314,
www.waterrfuelengineering.com

Appendix 2; Letter of Intent: Tavasya Venture

CIN- U74140OR2007PTC009653

**TAVASYA VENTURE**
**PARTNERS PRIVATE LIMITED**

***Ref: TVPPL/CPL/LOI/2018-19/012*** ***Date: 12th March, 2019***

***To,***

***Mr. Angel Nenov***
***Founder and Managing Director,***
***Water and Fuel Engineering***
***Office 3, Freemans House***
***8 Liquorice Way***
***Pontefract***
***WF8 1DR***

***Dear Mr Nenov***

**Congratulations on completion of your trials in Hyderabad with TSRTC.**

We are impressed with the principles behind your technology and appreciate your endeavor for a greener world. As you know India has a greater need of pollution control than anywhere else in the world and needs product like yours to reduce carbon foot prints.

Our discussions reflect that we can establish a variable cost base of 1/3$^{rd}$ of your current levels which would open up Indian potential market for this technology. As an organization we have versatile experience in Investment and Power sectors in India and have a prestigious network of the appropriate connections who can ensure the smooth roll-out of your product in India.

Identifying suppliers and establishing a manufacturing base are both areas for which you will need the experience and knowledge of an Indian partner. We would be happy to help you with both investment and in the practical development of the market including establishing a manufacturing Unit in India and look forward to discussing the next stage.

Regards

Ch. Prasanjit mishra

(Ch. Prasanjit Mishra)

Head Business Development

TAVASYA
enabling dreams

Registered Office: B-4, BJB Nagar, Kalpana Area, Bhubaneswar, Odisha - 751014
Corporate Office: 1/62/K/84, Plot No 84, Kavuri Hills, Phase-II, Hyderabad - 500081
040-23558701/720 040-23110775 contactus@tavasya.com www.tavasya.com

407 Britannia House, 1-11 Glenthorne,
London, W6 0LH, E-mail:
office@waterfuelengineering.com,
Tel./Fax: +44(0)1226 213 314,
www.waterrfuelengineering.com

Appendix 3; Expression of support; Compass Synergies; Sri Lanka

**Compass Synergies (Private) Limited**

82A Ward Place, Colombo 7, Sri Lanka

April 10th 2019

To:
**Mr. Pushpika Samarakoon**
Private Secretary to the Chief of Staff to the Prime Minister
Prime Minister's Office
Temple Trees
Colombo 3
Sri Lanka

Dear Mr. Samarakoon,

**Clean Buses in Sri Lanka**

Having met with Water Fuel Engineering, who were recently placed in the top 10 of the Transport-Technology Research Innovation for International Development fund sponsored by the UK Government Department of International Development high volume transport research program which supports to identify and share innovative concepts and solutions to the challenges facing the transport sector and given the immense success they have achieved in Hyderabad, India, I personally feel that Sri Lanka too would greatly benefit from this technology, given the current situation prevailing within the country.

We, as a nation must be more aware of the pollution caused by greenhouse gasses today as opposed to when some of these vehicles were manufactured, which was a generation ago. I envision that this product would be a much needed and sustainable solution, if structured, championed and managed the right way.

Water Fuel Engineering has expressed interest as stated in the summery of project report handed, to also expand this product offering to Sri Lanka and Jordon.

If approved, following a pilot project and approved reports of cost effectiveness and efficiently on Sri Lankan buses conducted with absolute transparency and accountability this can be considered as a golden opportunity for Sri Lanka to reduce the pollution (by almost 80%) caused by the local bus fleet which currently does NOT require emission certification. This will in turn be positively shown as the Government of Sri Lanka and Transport Ministry genuinely working towards an environmentally cleaner transportation fleet.

I sincerely urge the Prime Minister's office to evaluate the report given and assist in coordinating a meeting with the Minister of Transportation for us to discuss the possible next steps of this timely opportunity benefiting the nation.

Thanking you,

Darshan Maralanda
CEO

CC: Director, Water Fuel Engineering, UK

Appendix 4: E-Mail from Al-Wafra Industrial Co updating on progress.

info@al-wafra.com 11 May 2019 at 07:44

RE: cooperation

To: Phil Davies

Hello Phil,
Nice to hear from you again.
Regarding your experiments with Indian buses, was there any fuel cut down?
If yes, how much was it?
How much would one unit cost and what is the payback period?
Regarding heating I Jordan, I have come a long way, build my own HHO generator.
Still need some modifications and the most important thing is applying it to an existing heating system, which I intend to investigate this summer.
Kindly inform me your requirements so that I can come up with a plan.

BR,

Eng. Mahmoud Al-Ansari
شـركـة الوفرة الصناعية ذ.م.م
Al-Wafra Industrial Co. LLC
www.al-wafra.com
Tel 9626 41 637 05
Fax 9626 41 636 59
Mob. 962 79 55 1 22 45