# IVECO STRALIS LNG NATURAL POWER

## REPORT ON TESTING OF IVECO LNG VEHICLES IN POLAND


CRYOGAS M&T POLAND

IVECO

Your partner for sustainable transport


NATURAL
POWER

# Table of contents

# Introduction

## Definitions

| | |
|---|---|
| NGV | Natural Gas Vehicle |
| CNG | Compressed Natural Gas |
| LNG | Liquefied Natural Gas |
| IVECO | Manufacturer of natural gas fueled vehicles |
| IKEA | Customer participating in testing the use of LNG in road transport in its supply chain |
| Cryogas | Supplier of LNG and refueling infrastructure for LNG vehicles |

# Report objectives

This report aims to provide easy access to information on IVECO LNG-fueled vehicles and indicates the profitability of investment in vehicles fueled by liquefied natural gas (LNG).

# This report is intended for:

- Businesses with vehicle fleets
- Users of CNG and LNG fueled vehicles
- Representatives of state and local authorities
- EU Member States
- Public Administration as a guide with good practices in situation of insufficient legal & administrative support for implementation and maintanance of LNG powered vehicles and LNG refuelling stations
- Press and media
- Polish entrepreneurs operating on the methane fuel market
- Independent experts on the alternative gas fuel market
- Representatives of Research Institutions conducting studies on methane fuels
- Representatives of the international organizations raising awareness of environment friendly and economical CNG and LNG fuel usage in road transport
- Vehicle manufacturers
- Public and administration services
- Students in Higher Education and Vocational School Students
- Other persons, parties and organizations interested in supporting the development of vehicles powered by natural gas

*August 2016*

# Why LNG

This report has been prepared by IVECO as information as to possible use of IVECO LNG powered vehicles in large truck fleets.

It aims to facilitate the development of a market for low-carbon and efficient alternative fuels in Poland.

In this report we want to contribute to the enhancement and extension of knowledge about alternative, environmentally friendly LNG fuel to all industries.

„Natural gas and biomethane represent the most effective technology from all renewable energy sources, which is already available to help to reduce air pollution
in urban areas and emissions of $CO_2$. All our IVECO vehicles powered by CNG or LNG are suitable for biomethane, which has a highly strategic value for both the transport sector and European environmental policies."

*Pierre Lahutte, IVECO Brand President*

# Preface

Below we present the test results for IVECO Stralis LNG trucks carried out as part of implementation of economical and eco-friendly LNG-powered commercial vehicles on the Polish market.

IKEA, IVECO, and Cryogas decided to switch to ecological and economical LNG fuel and have demonstrated long-term savings in the transport sector. The project consisted of testing IVECO Stralis LNG trucks on routes used by IKEA's suppliers. The LNG supplies and LNG refueling infrastructure for conducted tests were provided by Cryogas.

# IVECO Stralis LNG Natural Power project for IKEA


LNG refueling station in Jarosty

Testing of LNG fueled vehicles lasted 6 months. The official handover of vehicles for testing in Jarosty near Piotrków Trybunalski was attended by representatives of companies participating in the project and invited guests. The aim of the IVECO-Cryogas -IKEA joint project was to test the refueling technology for alternative LNG fuel and to indicate to transport service pro-viders areas for development of sustainable transport using alternative methane-based fuels. The questions about the profitability and project success were addressed by representatives of the project in their respective presentations. The advantages of IVECO vehicles, powered by an alternative CNG and LNG fuel, were discussed by Michał Fersten, Sales Director of IVECO Poland:

***"IVECO is involved in the use of alternative methane-based fuels in road transport on a global scale.***

***We offer a whole range of our vehicles in the CNG version. As regards the vehicle being tested, the cruising range of Stralis CNG /LNG is 750 km, the vehicle systems feature relatively simple designs and the vehicle does not require the AdBlue additive. The fuel system in IVECO LNG tractor units meets all emissions standards and UNECE Regulation 110 concerning the approval of vehicles using the natural gas.***

Michał Fersten, IVECO POLAND

***Across Europe, we have already sold 14 thousand vehicles powered by natural gas, they are profitable, environmentally friendly and generate much less noise. In addition, the IVECO team constantly strives to optimize the purchase and maintenance cost of IVECO CNG/LNG trucks."***

***"Effective LNG refueling offered by Cryogas M&T Poland and smoothly testing of natural gas trucks prove sense of implementation of these economical and ecological commercial vehicles really makes sense" -*** said Jarosław Patyk, Cryogas Vice President. ***"In the last two years we have amassed a great deal of experience in using LNG gas as a fuel in propulsion machinery. Apart from joint tests carried out with IKEA and IVECO we built 2 LNG refueling stations during this time. But the most important advantage of our solution is that it guarantees a purchase of LNG fuel at competitive conditions and security of gas supply."***

During the meeting, IKEA underlined the main aim of the project, i.e. to check whether the use of an alternative fuel, considered to be more ecologically friendly and economical, will help IKEA reduce carbon dioxide emissions generated while transporting products.

# IKEA

IKEA – in cooperation with Cryogas M&T Poland and Iveco Poland – has entered into an agreement to carry out regular tests on the use of LNG in road transport in its supply chain. The aim of the project was to check whether the use of an alternative fuel, considered to be more ecologically friendly and economical, will help IKEA reduce carbon dioxide emissions generated while transporting products.

IKEA Regional Distribution Centre in Jarosty

In October 2014, IKEA Distribution Services SA, Cryogas M&T Poland SA and Iveco Poland Sp. z o.o. entered into a cooperation agreement with respect to testing LNG-powered trucks within the IKEA distribution network. One of the project objectives was to introduce all transport service providers for IKEA to this technology. Companies were also able to verify in practice the economic and technical aspects of applying it with respect to the Polish market.

***"To the best of my knowledge, this is the first pilot project regarding the use of LNG in road transport in Poland implemented on such a large scale. Experiences from other countries, mainly from the USA, United Kingdom, the Netherlands, and Spain, show that LNG is becoming a viable alternative to diesel fuel, which is commonly used in road transport. Thus it is worth a try to attempt implementing this new technology in our local market."*** said Marcin Barankiewicz, Transport Manager at IKEA in Poland.

Environmental benefits brought by using LNG are the main reason behind IKEA's decision to test it.

At IKEA, sustainable development constitutes an integral part of business activity, and this is why the company is committed to having a positive impact on people and the environment, and making various long-term investments. These also include transport operations, i.e. organizing the supply network and transporting products to stores directly from manufacturers or through the Distribution Center. In Poland, the company responsible for coordinating and performing these activities is IKEA Distribution Services SA, which in 2014 transported a total of 7.5 million m3 of products from manufacturers to final customers. This amount corresponds to 130,000 fully loaded trucks — out of which 25,000 were delivered to IKEA stores located throughout Poland, while the rest were exported to foreign markets, mainly in the European Union. Reduction of CO2 emissions in the supply chain by 30% in comparison to 2011, per m3 of transported goods, is the global objective of the company to be achieved by 2020, according to its sustainability strategy "People & Planet Positive". IKEA is implementing this principle through aiming to attain the highest possible fill rate for

means of transport, beginning even at the stage of product design and packing them into flat packaging, and ending with optimal methods of loading. IKEA is also continuously working to optimize the supply chain by shortening the distance between the production site and the target market, and by increasing the share of intermodal transport. Moreover, it cooperates with transport service providers, thus training drivers in ecological driving and investing in more economical and efficient vehicles. Only vehicles under 10 years of age are allowed for product transportation due to a large amount of pollutants emitted by older type trucks. Also undertakings concerning the use of alternative and renewable fuel technologies are being implemented. Cooperation with Iveco Poland and Cryogas M&T Poland was established as part of these activities..

## Overview of routes used for the truck testing in cooperation with IKEA

- ATC CARGO
  route: Jarosty – Radomsko
  average load weight 13.6 t
  Average fuel consumption during the test amounted to 23 kg/100 km

- ERONTRANS
  route: Jarosty – Stryków and Jarosty – Katowice
  average load weight 13.8 t
  Average fuel consumption 22 kg/100 km
- RABEN
  route: Jarosty – Poznań – Jarosty, Jarosty – Gdańsk, Iława/Brodnica/Łysomice – Lubawa
  Lubawa – Jarosty
  average load weight 15 t
  average fuel consumption 23.5 kg/100 km
- RABEN 2
  route: Jarosty - Poznań – Jarosty
  average load weight 21 t
  average fuel consumption 31 kg/100 km
- PODLASIE
  routes: Podlaskie, Warmian-Masurian, Pomeranian and Masovian Voivodeships
  average load weight 18.8 t
  average fuel consumption 33.9 kg/100 km

# IVECO

IVECO has always invested in research and technological innovations for environmental sustainability, and has brought a number of pace-setting ideas into play, also ensuring economic sustainability. IVECO has led the European sector for years both in research and the production of natural gas light, medium, heavy vehicles and buses, with around 25,000 Natural Gas engines produced and over 1,000 million km covered with its vehicles. For IVECO, Natural Gas technology is mature, reliable and economically sustainable.

The flagship model in IVECO's range of natural gas-powered vehicles is Stralis LNG with a cruising range of 750 km. The tractor AT440S33T/P LNG, in standard configuration, is equipped with four 70-liter CNG tanks and a 525-liter LNG cryogenic tank. Natural gas is stored in its liquid state at -130°C and at 9-bar pressure, which is then converted into a gaseous state before being injected into the engine.

The extensive product range for CNG fueled Stralis (with 2 and 3-axle rigids and 2-axle tractors) satisfies the numerous needs of the IVECO customers. The vehicles, manufactured on the same assembly line as diesel models at the IVECO plant in Madrid, are fitted with a Cursor 8 Natural Power engine, ranging from 270 to 330 hp. The engine is coupled to a 16-gear manual ZF transmission or 6-speed Allison automatic transmission with a hydraulic


torque converter. CNG models have an overall tank capacity ranging between 400 to 1,300 liters with layouts that can be tailored to suit customer needs.

Iveco is the only European manufacturer to have confirmed its CNG technology strategy in the evolution from Euro V to Euro VI: natural gas FPT Industrial engines are characterized by stoichiometric combustion, or in other words a chemically balanced air-fuel ratio; 100% fueled by natural gas; Otto cycle with spark plugs that ignite the air-fuel mixture injected by a rail, with two injectors per cylinder. Exhaust gas is treated by a standard passive three-way catalyst that does not require the use of any additives.


IVECO is a leading European manufacturer of Natural Gas vehicles: over 200 LNG vehicles are currently in circulation throughout Europe, chiefly in Spain and the Netherlands, where the appropriate infrastructure is well established. IVECO thus consolidates its commitment towards sustainable mobility without impairing progress, but responsibly combining it with environmental protection. This vision reflects the strategy that IVECO has chosen to implement in order to provide its customers with a wide range of technologically advanced vehicles in terms of environmental, safety and efficiency standards, while reducing operating costs.

# CNH Industrial as a leader in all aspects of natural gas application

IVECO and FPT are the European leaders in the application of natural gas, offering the most extensive range of CNG/LNG vehicles on the market:

More than 25,000 running vehicles with overall mileage > 1,000 million km

| | | EV/EEV | EVI | R&D | | |
|---|---|---|---|---|---|---|
| |  | ✓ | ✓ | ✓ | CNG | |
| IVECO |  | ✓ | ✓ | ✓ | CNG | |
| |  | ✓ | ✓ | ✓ | CNG | LNG |
| IVECO BUS |  | ✓ | ✓ | ✓ | CNG | |
| FPT POWERTRAIN TECHNOLOGIES |  | ✓ | ✓ | ✓ | CNG | |
| NEW HOLLAND AGRICULTURE |  | | | ✓ | CNG | |

# IVECO Natural Power
# - two decades of continuous investment

## COMMERCIAL VEHICLES

| LIGHT | MEDIUM | HEAVY |
|---|---|---|
| 3,5 do 7,2t | 11 do 16t | 18 do 44t |
| **6.500 VEHICLES** | **2.875 VEHICLES** | |

## BUSES

10, 12 & 18m

**5.500 VEHICLES**

## ENGINES

3.0 L / 6 L / 7,8 L

**29.000 ENGINES**

| | |
|---|---|
| **1996** | First bus, first commercial vehicle |
| **2000** | First light commercial vehicle |
| **2001** | First vehicle below Euro V |
| **2007** | First vehicle below Euro VI |
| **2010** | First LNG tractor |
| **2012** | First CNG tractor |
| **2015** | First LNG rigid truck |

# Cryogas M&T Poland S.A.

## Supplier of liquefied natural gas (LNG)

Cryogas is a renowned natural gas supplier with many years of LNG market experience. The company offers LNG supplies for distributors as well as end users satellite LNG stations throughout Poland. Liquefied natural gas is supplied using cryogenic semi-trailers, which guarantee the highest transport safety.

Cryogas' offer is aimed for companies seeking to use LNG for their technological processes and as vehicle and vessel fuel. As a supplier of liquefied natural gas, Cryogas offers innovative solutions regarding to investments related to the construction and operation of power installations. The Cryogas team of highly skilled experts is at customers' disposal and may assist in all matters related to construction of LNG refueling stations and supply of liquefied natural gas.

Along with the supply of LNG, the company provides attractive sale conditions and necessary infrastructure to the final use of natural gas. LNG refueling stations which the company has on offer enable regasification of the liquid phase and its use in industrial applications or for refueling vehicles and vessels.

Cryogas has know-how and experience in using LNG for other purposes too, e.g. emergency feeding of natural gas.


LNG refueling station

## 1. LNG supplies by road transport

LNG is transported from a liquefaction plant to the LNG station in specialized cryogenic semi-trailers, keeping a low temperature of liquefied gas during transport. A typical semi-trailers has a capacity of 18 tonnes, which after regasification makes possible 25,600 $Nm^3$ of natural gas in the gaseous form.


## 2. Cryogenic tanks

Dedicated for gas storage in liquefied form. Cryogenic storage tanks have varied capacities, with 60 $m^3$ being the most common. Such a tank can hold max. 24 tonnes of LNG, which is equivalent to 32,400 $Nm^3$ of natural gas. Technologically, it is possible to add more tanks to the LNG regasification station to obtain larger storage capacity. An LNG storage tank is specially designed to allow an LNG fueling installation to be connected to vehicles.


## 3. Cryogenic pump

Pumps the fuel to the LNG dispenser. The pump allows quick and efficient gas refueling. It takes only 5 minutes to put enough fuel into the tank of a vehicle to run for around 1,200 km.

## 4. LNG dispenser

The LNG dispenser measures the amount of fuel taken, and then an LNG vehicle – truck, bus or other heavy vehicle – is fueled by using a standardized nozzle.

# LNG as a transportation fuel

## Properties of LNG

Liquefied Natural Gas (LNG) is methane natural gas that has been converted to liquid form in order to facilitate transport and storage in areas beyond the reach of traditional gas networks or as a fuel for vehicles.

The natural gas is purified in a liquefaction terminal from among others carbon dioxide as well as moisture, and then cooled and condensed into a liquid. LNG is a safe substance with the same physical and chemical properties as a networked gas. Other LNG source are sea terminals.

On Polish territory LNG may be supplied from various sources, both onshore liquefaction plants and sea terminals. It ensures timely delivery of the customer's order and competitive prices. With regard to this issue LNG availability is not worse than that of diesel wholesale supply.

## Liquefied gas and compressed gas

| | LNG | CNG |
|---|---|---|
| |  |  |
| **Gas temperature** | - 163°C / - 130°C | Ambient temperature |
| **Storage** | Cryogenic tank [16 bar] (bunded, super isolation) | Pressure vessel [250 bar] (steel or composite) |
| **Gas odorization (THT)** | NO (sensors required) | YES (perceptible) |
| **Tank filling** | Liquid (90%), gas (10%) | Gas (100%) |
| **Calorific value, density** | 35,4 MJ/Nm$^3$, 390 – 420 kg/m$^3$ | |
| **Density** | 1.420 Nm$^3$ / per tonne | |
| **Compression [volume to gas ratio]** | 1 x 600 | 1 x 200 |
| **Requirements during refueling** | OHS<br>Goggles<br>Anti-static clothing | OHS |
| | Vehicle approval (formality), OHS | |

# Types of LNG refueling stations

## LNG fueling stations - design variations

| Full-size station | Skid mounted station | Container station |
|---|---|---|
| **Full area development** | **Station development** | **Back-up land for container** |
| **Vertical LNG tank** | **Horizontal LNG tank** | |
| **Refueling 50 or more vehicles** | **Refueling up to 50 vehicles** | |

# Installation requirements of LNG refueling facilities

LNG refueling stations can be set up wherever there are adequate maneuvering and servicing areas for heavy duty vehicles (access to dispensers and for fuel supply) and an electrical connection with output power of 20 kW.

Even the basic infrastructure equipment ensures fast refueling of LNG trucks at full capacity (max. 5 minutes). The amount of fuel supplied during that time allows the truck to drive more than 1,000 kilometers.

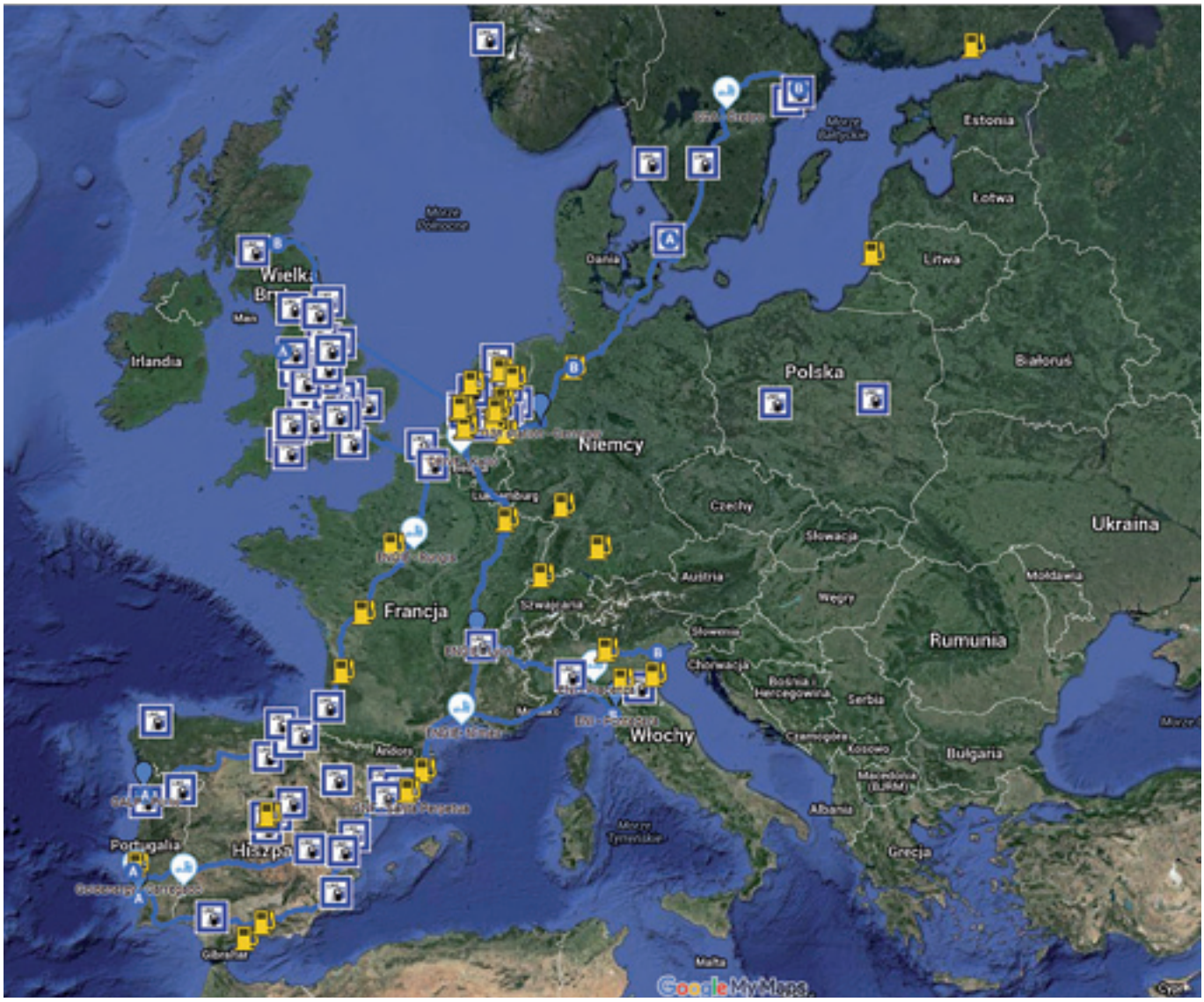
# LNG for the transport sector in Poland.

## LNG refueling stations for trucks

LNG refueling is provided by Przedsiębiorstwo Gospodarki Komunalnej in Śrem, where the Iveco Stralis LNG first LNG powered truck in Poland was put into operation. The station is easily accessible for trucks and is located along the 432 regional road (connecting Śrem and Zaniemyśl). Two other stations are located in Olsztyn and Warsaw and are dedicated for fueling buses.

All LNG refueling stations in Europe are showed on the map below.

Source: https://www.google.com/maps - LNG Blue Corridors - LNG stations in Europe



# Excise, market prospects.

## Current excise duty rate

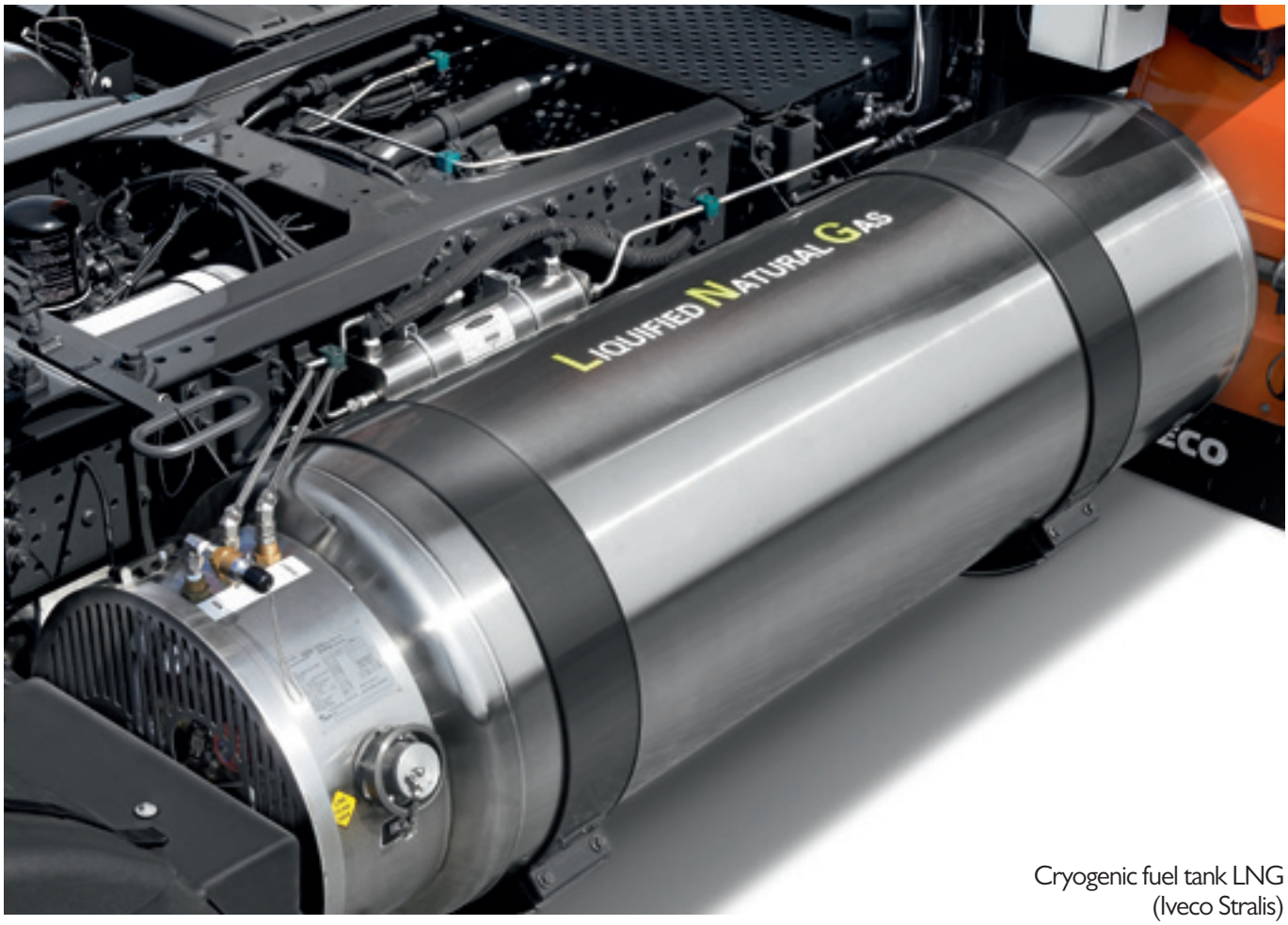
According to current law excise duty levied on liquefied natural gas for use as road fuel is PLN 670.00 (ca. EUR 153.00) per 1000 kg. In addition, LNG is levied with a fuel surcharge in the amount of PLN 159.71 (ca. 37.00 EUR) per 1000 kg.

## Comparison to LPG taxation

The current rate of LNG excise duty is comparable to the current rate for LPG (propane-butane). That indicates a regular pattern in gas levies being at a similar level.

## Stability of the excise duty rate

The current rate of excise duty has been in force since 2008. Currently there shall be no amendments to excise duty levied on LNG gas for use as road fuel, according to a statement of the Ministry of Finance of 30 December 2015. Taking into account state and the European Union conditions, any change in excise duty up until 2020 are unlikely.




Cryogenic fuel tank LNG
(Iveco Stralis)

# IVECO Stralis LNG

The Stralis Natural Power LNG is powered by a 330 hp Cursor 8 CNG Euro VI engine.

It is fitted with a 525 liter cryogenic LNG fuel tank and 4x70 liter CNG tanks, ensuring a fuel range of over 750 km. Thus, the vehicles can be used for medium and long distances.

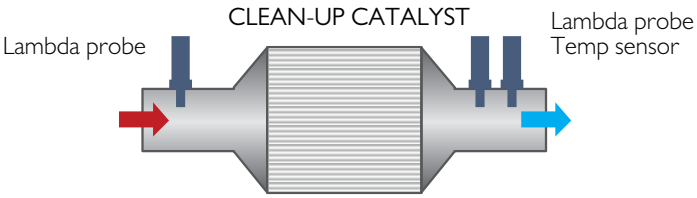
Using LNG-powered vehicles has many advantages in terms of environmental sustainability and profitability for customers. Indeed, in terms of emissions, natural gas engines are much more environmentally friendly than their diesel Euro VI counterparts. Natural gas is an absolutely clean fuel thanks to its emissions of particulate (-95% in comparison to diesel) and NOx (-35%) that have been slashed to a bare minimum. Furthermore, these vehicles make it possible to reduce vehicle emissions of CO2 from 10% up to 100% if using bio-methane. Lastly, Iveco proposes a more silent vehicle with an average decrease of 5 Decibels in comparison to diesel models, making it perfect for waste collection and night-time distribution.

With reference to cost effectiveness and savings in terms of the Total Cost of Ownership: natural gas is significantly less expensive when compared with diesel. This results in fuel costs being reduced by up to 40% (i.e. the most important factor when evaluating TCO).

**Soon IVECO will launch the new Stralis LNG with a capacity of 400 hp, perfectly suitable for international transport, with a greater cruising range, large cabin and automatic transmission.**

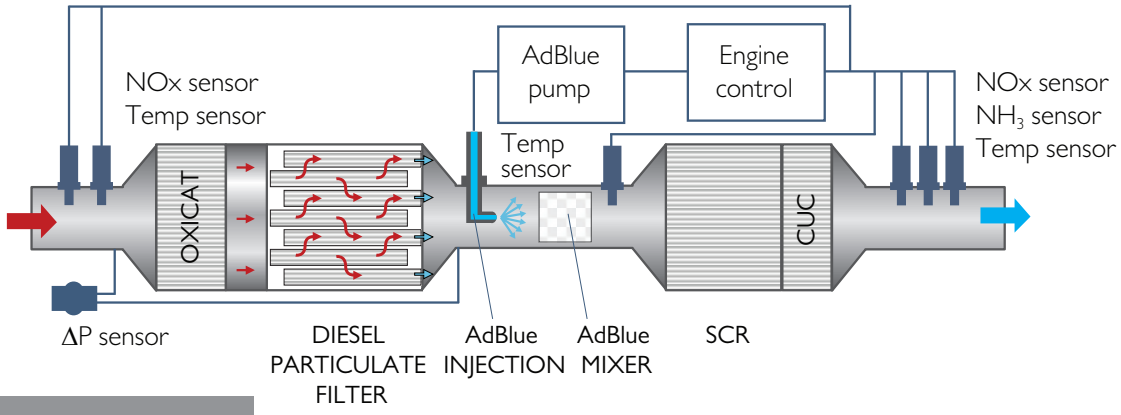
# Design

## Simplicity = Reliability = Profitability




**LNG Euro VI**

1 item
3 sensors
**45 kg**




**Diesel Euro VI**

4 items
7 sensors
**250 kg**

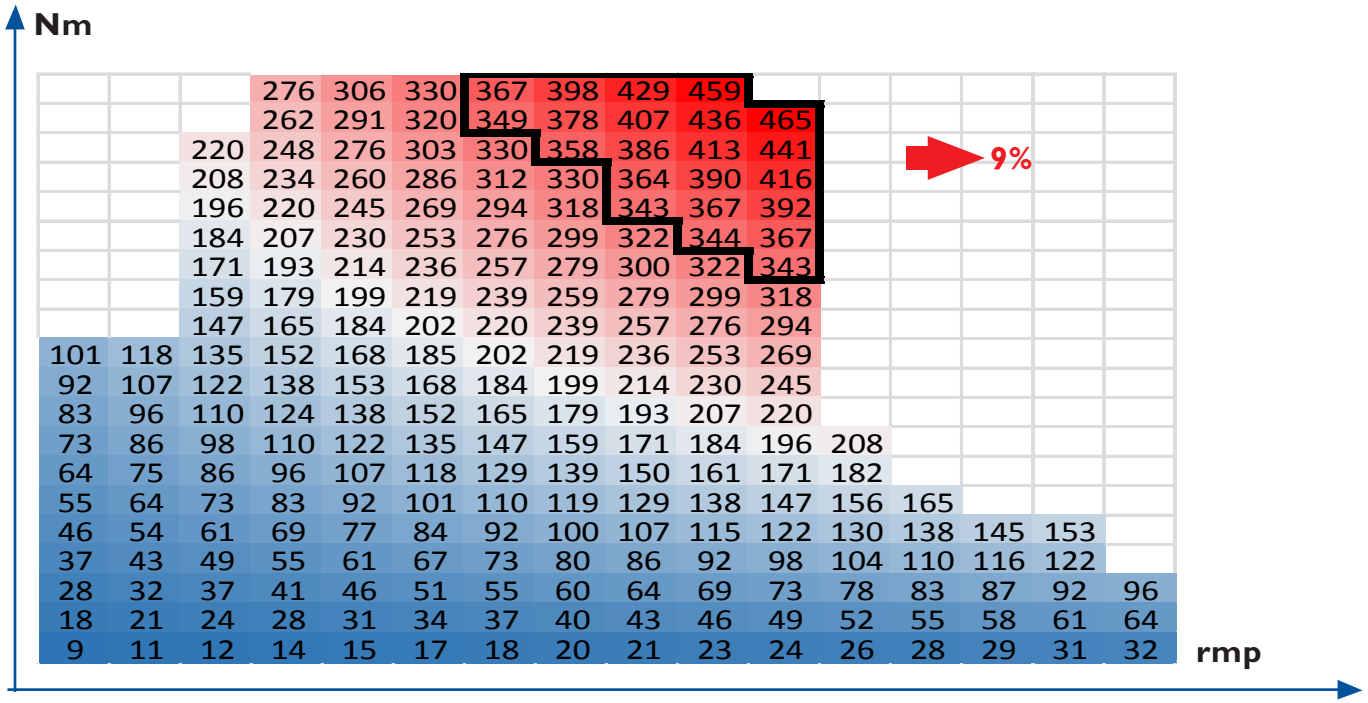
1 additive
1 pump
1 injection
1 mixer

| ADVANTAGES OF LNG |
|---|
| No EGR |
| No SCR |
| No AdBlue |
| No particulate filter |
| No additional fuel injection |
| No diesel oil and its derivatives |

| ADDITIONAL BENEFITS OF BIO LNG |
|---|
| No use of fossil fuels |
| No need to import fuel |
| No need to extract fuel |
| It comes from renewable sources (e.g. waste) |

# Road performance

| Diesel 460 hp vs. 330 hp LNG at a load of 41 t | |
|---|---|
| **Mission:** 240 km in 4h 45min<br>City + Motorway + Mountainous terrain + Local roads | |
| **% of time over 330 hp** | **9 %** |
| Average speed vs. 330 hp LNG | **SAME** |

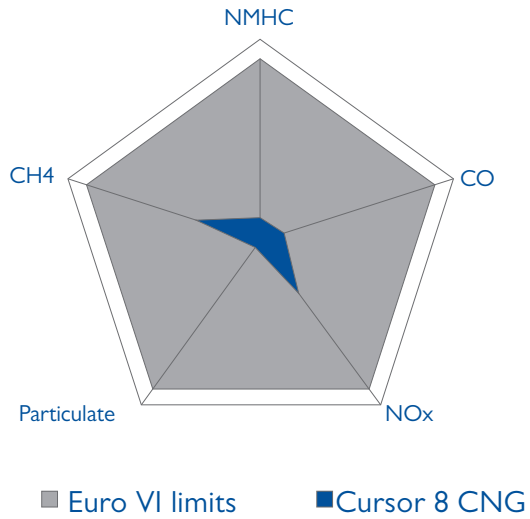



| STRALIS CNG & LNG | | | |
|---|---|---|---|
| **DMC** | **Route type** | **Topography** | **Driving performance** |
| [19 - 32] | Motorways | Flat | **Excellent** |
| | | Hilly | **Excellent** |
| | Local roads | Flat | **Good** |
| | | Hilly | **Good** |
| [40 – 44] | Motorways | Flat | **Good** |
| | | Hilly | **Acceptable** |
| | Local roads | Flat | **Limited** |
| | | **Hilly** | **Poor** |

# Environmental Benefits

## Global response to air pollution caused by transport

### Air Quality




**Global Warming**

- **10 to 15%** reduction of $CO_2$, which gives annually:
- **Up to 19 tonnes** of $CO_2$ less per vehicle
- **Up to 100 tonnes of** $CO_2$ less per vehicle powered by Bio-LNG

**Hałas**

- 3 dB noise reduction
- Piek Quiet Truck Certificate (72 dB)
- Suitable for night deliveries

| APPROVED EMISSION VS. EURO VI LIMITS | | | |
|---|---|---|---|
| 70 % less NOx | 96 % less PM | 90 % less NMHC | 88 % less Methane |

### Very low NOx and particulate emissions to protect our health

| LNG vs. DIESEL Euro VI | |
|---|---|
| NOx emissions | -54% |
| NO2 emissions | -96% |
| CO2 emissions | -10% |
| External costs (2009/33 EU) | -4 885 €<br>(-14%) |
| Fuel consumption | -15% (kg vs L) |
| **PORTABLE EMISSION MEASUREMENT SYSTEM (PEMS)** | |

# Diesel vs LNG

| | DIESEL | LNG |
|---|---|---|
| **consumption** | 31 L /100km | 28 kg / 100km |
| **mileage - 1 year** | 120.000 km | 120.000 km |
| **total consumption** | 37.200 litrów | 33.480 kg |
| **$CO_2$** | 2,65 kg / l | 2,74 kg / kg |
| **$CO_2$ emissions / year** | 98.580 kg | 91.735 kg |
| **$CO_2$ reduction / year** | | -6.845 kg<br>-7% |

# Location of LNG refueling point for test routes


LNG refueling of an Iveco Stralis truck

Setting up a temporary LNG refueling station fuel for IVECO - IKEA - Cryogas testing project took about 3 months. The time for setting up such an LNG station is determined by obtaining the necessary permits. Management of a comprehensive project investment process and installation of an LNG refueling station was conducted by Cryogas, which included obtaining necessary permits, engineering the complete project design, execution of works according to the requirements of the Polish Office of Technical Inspection, and obtaining the occupancy permit (complete FEED and EPC process). A cryogenic semi-trailer was used as the LNG storage tank, maintaining a required low temperature of liquefied gas. The amount of fuel taken was measured by an LNG dispenser. LNG vehicle was fueled by using a standardized nozzle. Filling up a vehicle (180 kg of LNG) took about 25 minutes and was performed by using the pressure difference. For test purposes this form of vehicle refueling was acceptable.

The LNG price is based on the conventional parity between 1 kg of gas and current prices of 1 liter of PKN ORLEN's EkoDiesel diesel fuel. The LNG price includes excise duty and fuel surcharge as well as a fee for leasing a refueling system. Along with refueling point for LNG-powered trucks, Cryogas has provided personnel to per-form refueling operations. Continuous, re-mote monitoring of the technical status of a station has been implemented - including the control of amount of fuel in the stationary tank and current equipment status.

# Test results for IVECO LNG tractors


| | |
|---|---|
| Test duration: | 6 months = 1 June 2015 - 30 November 2015 |
| Number of tested vehicles: | 3x IVECO Stralis AT 440S33 TP LNG tractors. Two tractors with a high cabin, one with a low cabin. |
| Number of transportation companies participating in tractor testing: | 5 |
| Number of tested routes: | 5 |
| Tested fuel: | LNG, and CNG fuel in emergency cases (approx. 150 km mileage on CNG), in the carried out test CNG emergency fueling was not used. |

## Table with summary of test results

| Route | Total length of routes [km] | Average load weight [t] | Total LNG fuel [kg] | Average LNG fuel consumption [kg/100 km] | Average diesel consumption [L/100 km] | Combustion ratio LNG/ diesel [%] |
|---|---|---|---|---|---|---|
| 1 | 1,615 | 13.6 | 372,7 | 23.08 | 31.00 | 74% |
| 2 | 14,149 | 13.8 | 3,129.6 | 22.12 | 31.00 | 71% |
| 3 | 17,903 | 15.0 | 4,303.2 | 24.04 | 29.00 | 83% |
| 4 | 1,157 | 21.0 | 360.0 | 31.11 | 31.30 | 99% |
| 5 | 5,733 | 18.8 | 1,943.4 | 33.90 | 33.00 | 103% |
| | 40,557 | | 10,108.9 | | | |

Average diesel consumption taken for comparison came from tractors with capacity well above of those in LNG vehicles.

## Summary of test results:

- Total distance covered: 40 557 km
- Total LNG fuel consumption: over 10,108.0 kg
- Average load weight: 13.6 - 21.0 tonnes
- Weighted average of load weights during the tests: 15.3 tonnes
- Weighted average of LNG consumption during the tests: 24.93 kg/100km
- Weighted average diesel consumption during the tests for comparison: 30.41 kg/100km
- Combustion ratio LNG/diesel during the tests: 82%

Tested vehicles were travelling on roads in the Pomeranian, Warmian-Masurian, Podlaskie, Masovian, Łódź, Wielkopolska, and Silesian Voivodships. The roads in these regions are relatively low in gradient.

Vehicles were not travelling in hilly areas during the tests.

Based on analyzed data and weighted averages (being more accurate calculation of the average fuel consumption than the arithmetic mean) it can be concluded definitively that there is a relationship between the load weight and the consumption of LNG fuel (a similar relationship can be noted for diesel fuel).

- Transportation of goods up to 13.8 tonnes appeared to be the most cost-effective (with a LNG/diesel combustion ratio of approx. 74%, which means that a vehicle's consumption of LNG is 26% lower than consumption of diesel for the respective route).
- For loads up to 15 tonnes the combustion ratio is 83%, which is almost identical to the average of the whole test period (82%).
- The least cost-effective transport using LNG fuel was the transporting of loads of 18 tonnes and above. The LNG/diesel combustion ratio is then equal to 1:1 or even higher (103%).

With increasing load weight the LNG consumption increases faster than that of diesel (the ratio changes from 71% to 103%), resulting in diminished cost-effectiveness of gas, used as a fuel.

This fact directly affects the level of return of the overall investment, despite the fact that the purchase price of LNG is lower than diesel.

# Test results per company

**Route No. 1 - average load weight 13.6 t - LNG consumption 23.08 kg/100 km (tractor with high cabin)**

Short routes (length approx. 50 km), mainly local roads between the warehouse and container terminal. Average load weight 13.6 t. Fuel consumption amounted to 23.08 kg/100 km. In total, the traveled distance amounted to 1615 km with LNG consumption of 372.7 kg.

Diesel powered vehicles reached an average fuel consumption of 31 L/100 km on this route. The LNG/diesel combustion ratio amounted to 74%.

**Route No. 2 - average load weight 13.8 t - LNG consumption 22.12 kg/100 km (tractor with high cabin)**

Short (length approx. 60 km) and medium (approx. 160 km) routes, mainly national expressways, but also local roads. Average load weight 13.8 t. Fuel consumption amounted to 22.12 kg/100 km. In total, the traveled distance amounted to 14,149 km with LNG consumption of 3129.6 kg.

Diesel powered vehicles reached an average fuel consumption of 31 L/100 km on this route. The LNG/diesel combustion ratio amounted to 71%.

**Route No. 3 - average load weight 15.0 t - LNG consumption 24.04 kg/100 km (tractor with high cabin)**

Short (length approx. 40 km) and medium (approx. 100 km) along local roads and long routes (approx. 350 km), mainly national expressways. Average load weight 15.0 t. Fuel consumption amounted to 24.04 kg/100 km. In total, the traveled distance amounted to 17,903 km with LNG consumption of 4,303.2 kg.

Diesel powered vehicles reached an average fuel consumption of 29 L/100 km on this route. The LNG/diesel combustion ratio amounted to 83%.

**Route No. 4 - average load weight 21.0 t - LNG consumption 31.11 kg/100 km (tractor with high cabin)**

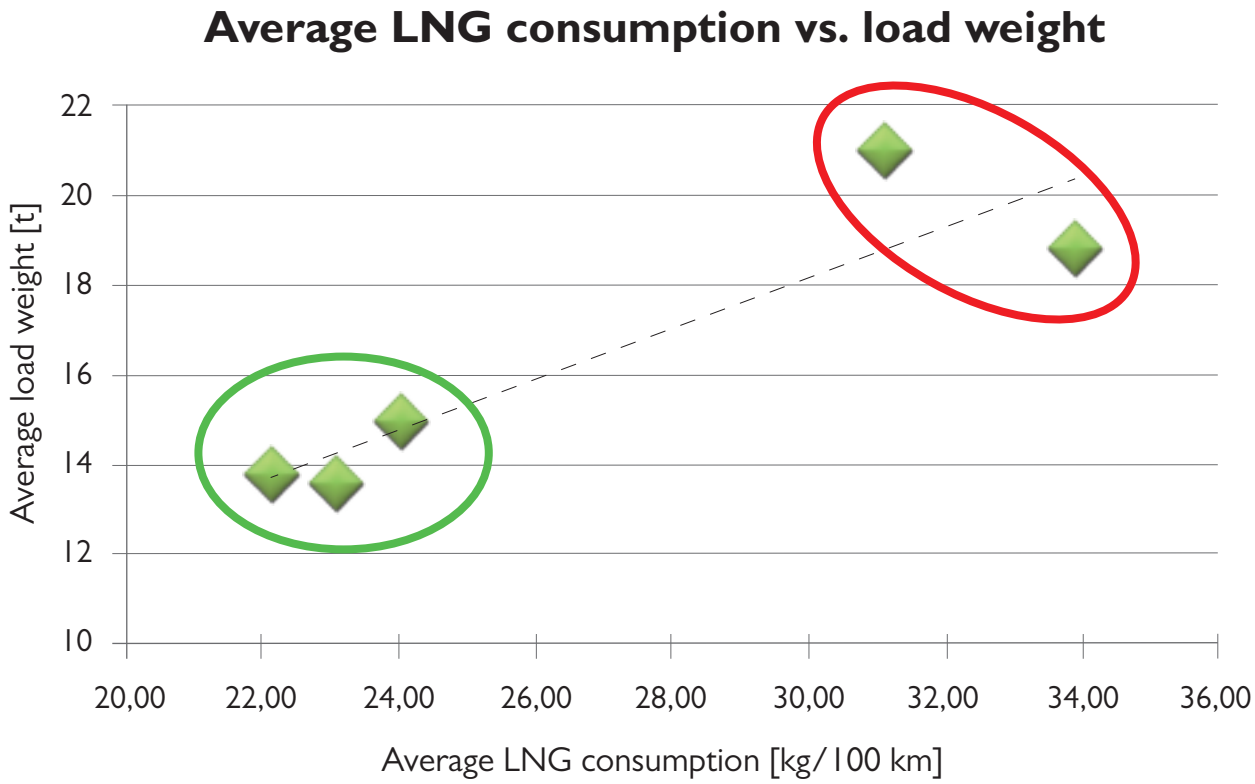
Long routes (approx. 250 km), mainly national expressways. Average load weight 21.0 t. Fuel consumption amounted to 31.11 kg/100 km. In total, the traveled distance amounted to 1,157 km with LNG consumption of 360.0 kg.

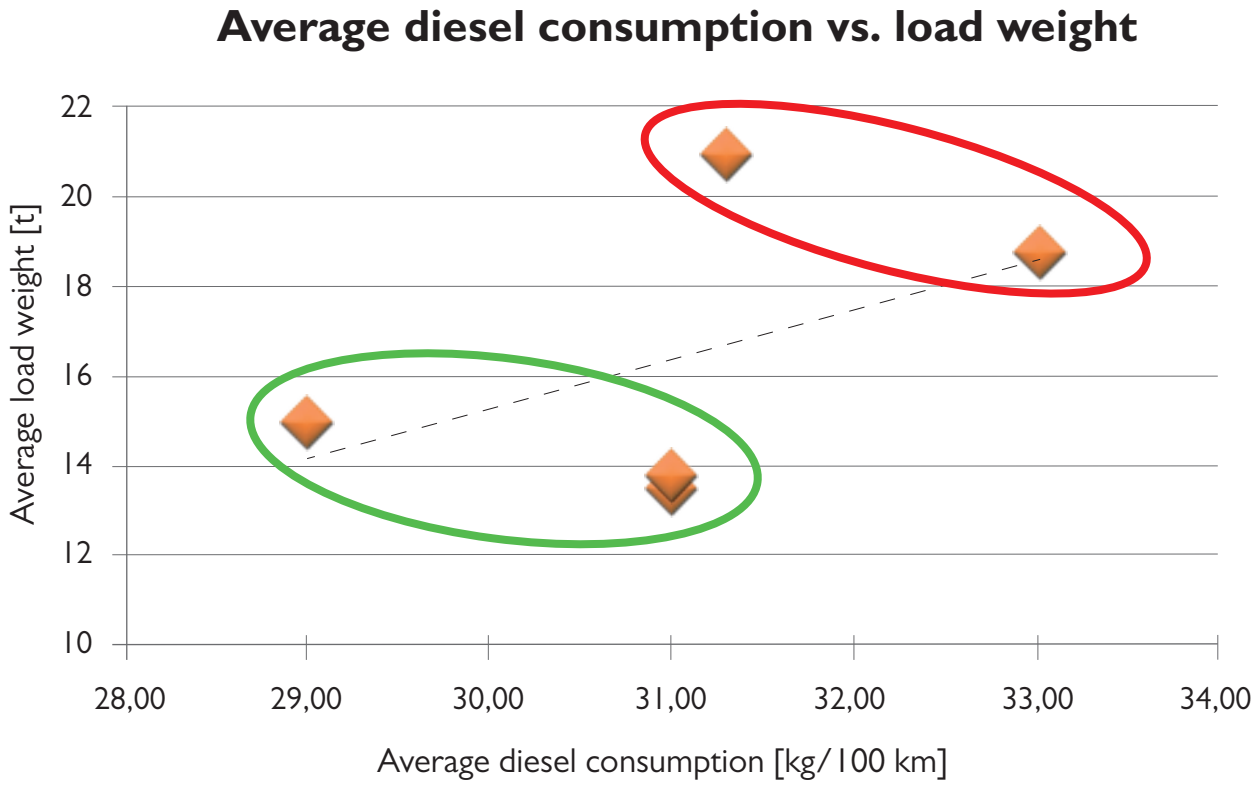
Diesel powered vehicles reached an average fuel consumption of 31.30 L/100 km on this route (calculated on the assumption of 25 L/100 km consumption per empty set plus 0.3 L/100 km consumption per each 1 tonne of cargo). The LNG/diesel combustion ratio amounted to 99%.

**Route No. 5 - average load weight 18.8 t - LNG consumption 33.90 kg/100 km (tractor with high cabin)**

Routes varied in length, along local roads in the Podlaskie Voivodeship, Warmian-Masurian Voivodeship, and Pomeranian Voivodeship. Average load weight 18.8 t. Fuel consumption amounted to 33.90 kg/100 km. In total, the traveled distance amounted to 5,733 km with LNG consumption of 1,943.4 kg.

Diesel powered vehicles reached an average fuel consumption of 33.00 L/100 km on this route. The LNG/diesel combustion ratio amounted to 103%.


Average LNG consumption vs. load weight
Average load weight [t]
22
20
18
16
14
12
10
20,00
22,00
24,00
26,00
28,00
30,00
32,00
34,00
36,00
Average LNG consumption [kg/100 km]


Average diesel consumption vs. load weight
Average load weight [t]
22
20
18
16
14
12
10
28,00
29,00
30,00
31,00
32,00
33,00
34,00
Average diesel consumption [kg/100 km]

# Total Cost of Ownership (TCO) Analysis

The analysis was conducted for diesel and LNG powered tractors with comparable engine power (330 hp):

- **Iveco Stralis AT 440S33 TP**
- **Iveco Stralis AT 440S33 TP LNG**

The diesel powered tractor with a power rating of 330 hp is not a popular vehicle on the Polish market, but the aim of the analysis was to compare the costs for vehicles as similar to each other as possible.

The project involved a 5-year lease term with an annual vehicle mileage = 85,000 km (7,083 km per month).

**Cost items taken into account in the analysis:**

- **Leasing** – financing service by Iveco Capital:
  - 5 years (60 months)
  - Initial fee 0%
  - EUR Currency,
  - Bargain purchase value at the end of the lease period 20%
- **3XL-Life maintenance and repair contract** – top service contract in Iveco's Elements program, most often chosen by customers. It includes:
  - Periodic inspections (maintenance, lubrication, fluid replacement services, according to the schedule set forth in the service book)
  - Powertrain warranty (repair services for engine, fuel system, transmission, drive shaft and drive axles)
  - Wear warranty (clutch, brake pads and brake discs, brake drums and linings for drum brakes, shock absorbers, suspension parts)
  - Other repairs (outside the drive system)
- Fuel and AdBlue consumption - for a diesel powered vehicle AdBlue consumption amounts also to 8.5% per 100 km.
- Vehicle Insurance - insurance coverage granted by Gras Savoye Poland. Full coverage insurance including civil liability, AC, accident insurance and return to invoice insurance (payment of the claim for the total/theft loss up to the sum insured for the whole financing period).

For the purpose of the simulation, it was assumed that the price of 1 kg of LNG fuel is equivalent to 85% of the net wholesale price of 1 liter of Eco-diesel offered by PKN Orlen S.A. It is possible to achieve these price levels for a fleet consisting of 50 LNG trucks.

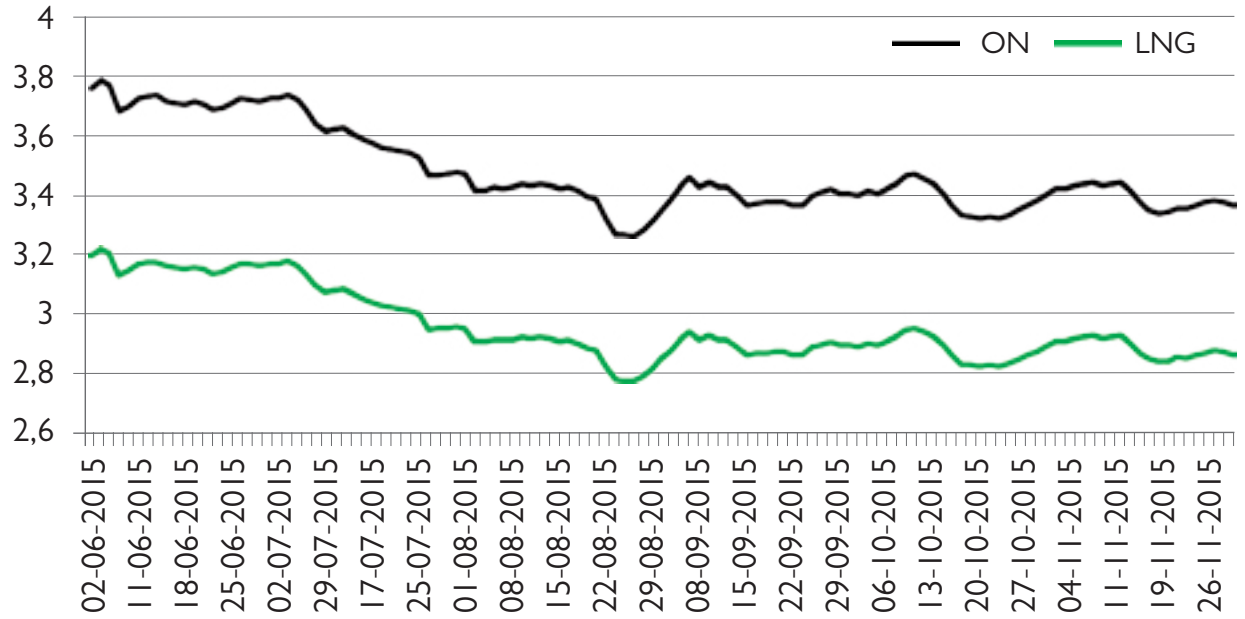
For a project economic analysis the following prices were assumed:

- Average selling price of 1 liter of Ekodiesel diesel fuel offered by PKN Orlen S.A. during 06-12/2015 = PLN 3.48
- Average selling price of 1 kg of LNG fuel (85% of diesel price) during 06-12/2015 = PLN 2.95
- Average EUR exchange rate (Table A of NBP - average exchange rates of foreign currencies) during 06-12/2015 = PLN 4.2039
- Price of AdBlue additive taken for analysis = PLN 1.19

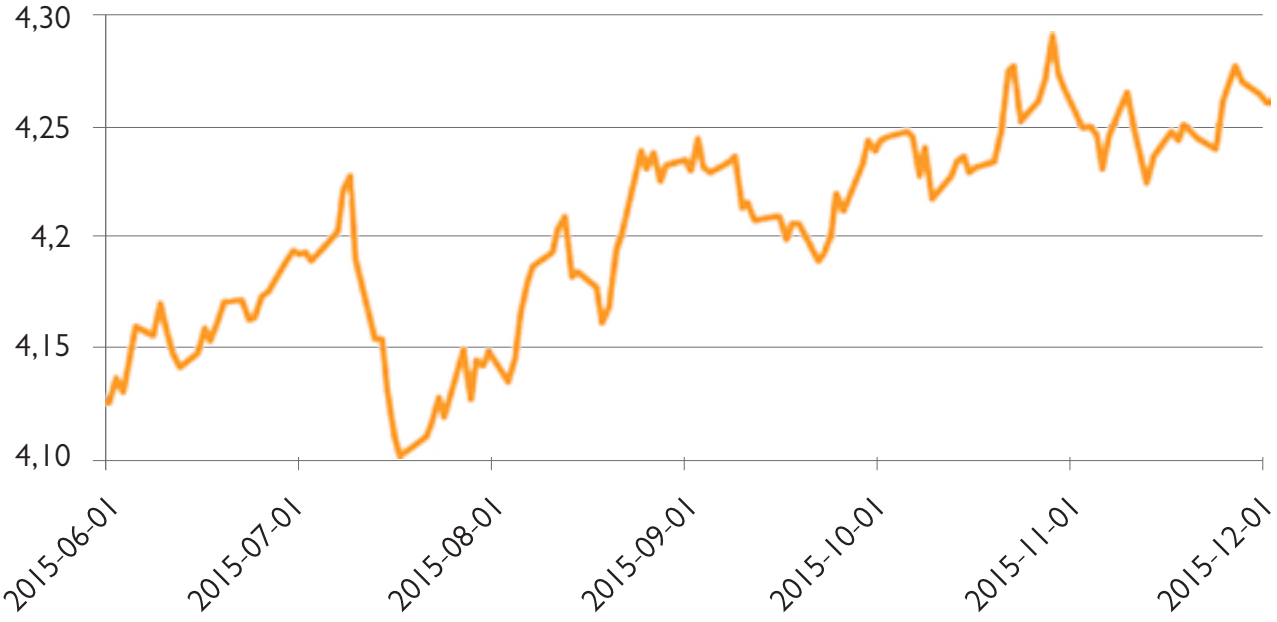
Data for the test period:

- Weighted average of LNG consumption during the tests: 24.93 kg/100km
- Weighted average diesel consumption during the tests for comparison: 30.41 kg/100km
- Combustion ratio LNG/diesel during the tests: 82%

## Fuel prices in the test period [PLN]




## EUR exchange rate in the test period



| **Lease term in years** | **5** | **5** | |
|---|---|---|---|
| **Assumed annual mileage** | **85,000** | **85,000** | |
| **Fuel type** | **Diesel Euro 6** | **LNG** | **Difference** |
| Model | **AT 440S33 TP** | **AT 440S33 TP LNG** | |
| **Monthly lease payment with 3XL- Life service contract** | **1,022.84 €** | **1,646.37 €** | **623.53 €** |
| Monthly fuel cost | 1,780.75 € | 1,240.87 € | -539.87 € |
| Monthly AdBlue cost | 51.83 € | 0.00 € | -51.83 € |
| **Fuel and AdBlue cost** | **1,832.58 €** | **1,240.87 €** | **-591.70 €** |
| **Monthly insurance cost** | **119.87 €** | **195.50 €** | **75.63 €** |
| **Monthly TCO** | **2,975.29 €** | **3,082.74 €** | **107.45 €** |
| **Annual TCO** | **35,703.47 €** | **36,992.85 €** | **1,289.38 €** |
| **5-year TCO** | **178,517.34 €** | **184,964.25 €** | **6,446.91 €** |
| | | | **3.6%** |

Table of total cost of ownership - TCO (5-year lease, 85,000 km per year)

For the following assumptions: 5-year lease and 85,000 km per year, total cost of ownership (TCO) of the LNG-powered tractor is EUR 6,447 higher than a comparable diesel-powered vehicle over a 5-year period (EUR 1,289 per year).

Monthly lease payments for a tractor have a decisive impact on the TCO. Including the service contract, the monthly payment for an LNG powered vehicle is 60.9% higher than a diesel vehicle (about EUR 624 per month). The insurance cost of an LNG vehicle is also higher than a diesel powered one by 62.5% (about EUR 76 per month).

The main advantages of an LNG powered tractor are lower fuel cost (profit of EUR 592 per month) and lower service contract cost (profit of EUR 59). This advantage will increase in line with expected mileage. The average return on LNG fuel that is made per each run kilometer is: 0.084 EUR.

| **Lease term in years** | **5** | **5** | |
|---|---|---|---|
| **Assumed annual mileage** | **105,000** | **105,000** | |
| **Fuel type** | **Diesel Euro 6** | **LNG** | **Difference** |
| Model | **AT 440S33 TP** | **AT 440S33 TP LNG** | |
| **Monthly lease payment with 3XL- Life service contract** | **1,043.74 €** | **1,684.39 €** | **640.65 €** |
| Monthly fuel cost | 2,199.75 € | 1,532.84 € | -666.90 € |
| Monthly AdBlue cost | 64.02 € | 0.00 € | -64.02 € |
| **Fuel and AdBlue cost** | **2,263.77 €** | **1,532.84 €** | **-730.93 €** |
| **Monthly insurance cost** | **119.87 €** | **195.50 €** | **75.63 €** |
| **Monthly TCO** | **3,427.38 €** | **3,412.73 €** | **-14.65 €** |
| **Annual TCO** | **41,128.57 €** | **40,952.76 €** | **-175.81 €** |
| **5-year TCO** | **205,642.86 €** | **204,763.80 €** | **-879.06 €** |
| | | | **-0.4%** |
| **Profit after 1 year on 10 vehicles** | | | **1,758.11 €** |
| **Profit after 5 years on 10 vehicles** | | | **8,790.56 €** |

Table of total cost of ownership - TCO (5 lease, 105,000 km per year)

**The break-even point for investments in an IVECO LNG vehicle considering the above assumptions is reached for mileages exceeding 105,000 km per year.**

Then the monthly savings on LNG fuel and the service contract will outweigh the other vehicle operating costs (TCO).
For the following assumptions: 5-year lease and 105,000 km per year, total cost of ownership (TCO) of the LNG-powered tractor is EUR 879 lower than a comparable diesel-powered vehicle over a 5-year period (EUR 176 per year).

| **Lease term in years** | **5** | **5** | |
|---|---|---|---|
| **Assumed annual mileage** | **120,000** | **120,000** | |
| **Fuel type** | **Diesel €6** | **LNG** | **Difference** |
| Model | **AT 440S33 TP** | **AT 440S33 TP LNG** | |
| **Monthly lease payment with 3XL- Life service contract** | **1,080.75 €** | **1,09.37 €** | **628.62 €** |
| Monthly fuel cost | 2,514.00 € | 1,751.82 € | -762.18 € |
| Monthly AdBlue cost | 73.17 € | 0.00 € | -73.17 € |
| **Fuel and AdBlue cost** | **2,587.17 €** | **1,751.82 €** | **-835.35 €** |
| **Monthly insurance cost** | **119.87 €** | **195.50 €** | **75.63 €** |
| **Monthly TCO** | **3,787.78 €** | **3,656.69 €** | **-131.10 €** |
| **Annual TCO** | **45, 453.42 €** | **43,880.24 €** | **-1,573.18 €** |
| **5-year TCO** | **227,267.09 €** | **219,401.20 €** | **-7,865.89 €** |
| | | | **-3.5%** |
| **Profit after 1 year on 10 vehicles** | | | **15,731.79 €** |
| **Profit after 5 years on 10 vehicles** | | | **78,658.93 €** |

Table of total cost of ownership - TCO (5-year lease, 120,000 km per year)

**Sample profit at mileage of 120,000 km per year.** Taking into account the prices assumed during the test for a 5-year lease with an annual mileage of 120,000 km, an LNG powered vehicle generates savings of EUR 1,573 per year (EUR 7,866 in 5 years). When considering the purchase of 10 LNG powered tractors, the possible savings over a 5-year period may amount to EUR 78,656.

| **Lease term in years** | **5** | **5** | |
|---|---|---|---|
| **Assumed annual mileage** | **150,000** | **150,000** | |
| **Fuel type** | **Diesel €6** | **LNG** | **Difference** |
| Model | **AT 440S33 TP** | **AT 440S33 TP LNG** | |
| **Monthly lease payment with 3XL- Life service contract** | **1,122.66 €** | **1,767.12 €** | **644.45 €** |
| Monthly fuel cost | 3,142.49 € | 2,189.77 € | -952.72 € |
| Monthly AdBlue cost | 91.46 € | 0.00 € | -91.46 € |
| **Fuel and AdBlue cost** | **3,233.96 €** | **2,189.77 €** | **-1,044.18 €** |
| **Monthly insurance cost** | **119.87 €** | **195.50 €** | **75.63 €** |
| **Monthly TCO** | **4,476.49 €** | **4,152.38 €** | **-324.10 €** |
| **Annual TCO** | **53,717.87 €** | **49,828.62 €** | **-3,889.25 €** |
| **5-year TCO** | **268,589.33 €** | **249,143.09 €** | **-19,446.24 €** |
| | | | **-7.2%** |
| **Profit after 1 year on 10 vehicles** | | | **38,892.48 €** |
| **Profit after 5 years on 10 vehicles** | | | **194,462.39 €** |

Table of total cost of ownership - TCO (5-year lease, 150,000 km per year)

Sample profit at mileage of 150,000 km per year. Taking into account the prices assumed during the test for a 5-year lease with an annual mileage of 150,000 km, an LNG powered vehicle generates savings of EUR 3,889 per year (EUR 19,446 in 5 years).

When considering the purchase of 10 LNG powered tractors the possible savings over a 5-year period may amount to EUR 194,462.

# LNG for the transport sector - offer for transport operators

## Ratio of LNG and PKN Orlen's Ekodiesel fuel wholesale price

The savings on fuel are the main incentive for companies when deciding to switch to LNG gas. The factor which contributes to generating profits is a constant, lower parity between LNG pricing and PKN Orlen's Ekodiesel fuel wholesale price. For an operator of a fleet consisting of diesel powered vehicles who decides to switch to liquefied natural gas this parity ensures that this decision will pay off in any conditions. This solution ensures that the operator will remain competitive compared to other transport companies operating on the market which have diesel powered vehicles. Another argument in favor of making use of the pricing of PKN Orlen's Ekodiesel diesel fuel is that it is very competitive to other wholesale prices of diesel fuels available on the market (e.g. offered by Lotos or German refineries).

Implementation of a fleet comprising at least 50 LNG trucks for each refueling station means an 85% parity can be achieved of the wholesale diesel price (detailed calculations in this regard are presented in the TCO analysis on page 33).

## Parity between the price of LNG and diesel and other pricing mechanisms

There are also proposals submitted by market players to determine the price of LNG on the basis of other indices, e.g. prices of 3 basic fuels (residual fuel oil, propane-butane and TTF natural gas). The vulnerability of these measures is that they reflect the trends of natural gas demand in industry or public utilities for heating and domestic purposes.

In both cases fluctuation in prices depend, among others, on the heating seasons and other factors not directly related to the transport industry. There are not indices equally transparent to transport companies as the wholesale diesel prices.

In Poland there have also been instances in which the price of natural gas used as a fuel is linked to the price list published by one of the gas companies. In this case, it is a non-market solution, reflecting the commercial policy of the company operating on the grid gas market. The published price list is in fact the result of the internal calculations of such company and does not faithfully reflect the market dynamics.

# LNG deployment scenario for potential transport companies

The core of the LNG refueling station network for transport companies interested in the implementation of vehicles powered by natural gas will be an LNG container refueling station near Piotrków Trybunalski or Łódź. It will serve dozens of LNG trucks a day. "Main Station" will become operational in the first quarter of 2017.

The next stage will include installing LNG container stations at LNG transport network nodes located near Gdańsk/Gdynia, the Silesian Agglomeration, Poznań and Warsaw. LNG refueling container stations will enable to refuel several trucks a day.

"Auxiliary stations" will become operational in the second quarter of 2017.

All facilities set up for potential transport companies shall meet the following standards:

1. Fast refueling - an LNG powered truck will be refueled in up to 10 minutes
2. Simple to use and simple self-service after general driver training
3. Cashless payment settlement - based on specially designated RFID cards
4. Fixed trading terms depending on the volumes of purchased gas
5. Servicing LNG refueling and payments for purchased fuel by one entity

Till 2025 gas companies operating on the Polish market will make available LNG refueling stations along the Trans-European Transport Networks (TEN-T) every 400 km. It will include the A1, A2, S3, A4, S7, S8 and S61 roads.

# Summary

## The main advantages of an LNG powered tractor are lower fuel costs and lower service contract costs.

Over 6 months, 3 IVECO Stralis AT 440S33 TP LNG tractors travelled in total over 40,000 km, a distance comparable with the circumference of the globe. More than 10 thousand kilograms of fuel were consumed. Average LNG fuel consumption amounted to 24.93 kg/100 km at the average load weight of 15.3 tonnes (weighted average of diesel consumption during the tests assumed for comparison was 30.41 L/100 km).

Tests showed that transportation of goods up to 13.8 tonnes appeared to be the most cost-effective, while the least cost-effective transport was when transporting loads of 18 tonnes and above. With an increase in load weight LNG consumption increases faster than that of diesel.

The LNG/diesel combustion ratio for the smallest loads is approx. 74%, which means that the vehicle consumes 26% less LNG than diesel on the respective route. This ratio varies with the increase of load weight and amounts to 103% for the heaviest goods, resulting in decreasing cost-effectiveness of using gas as a fuel. The average LNG/diesel combustion ratio during the test amounted to 82%.

This fact directly affects the level of return of the overall investment, despite the fact that the purchase price of LNG is lower than diesel.

**The TCO analysis** for a given mileage of 85,000 km per year, taking into account the 5-year lease, and taking into account the costs of the service contract, fuel and insurance assumed for the testing demonstrated unequivocally that LNG fuel is not cost-effective for such low mileages.

The total cost of ownership (TCO) of the LNG-powered tractor is higher than a comparable diesel-powered vehicle by EUR 6,447 over a 5-year period. The decisive factor here, however, was the amount of the lease payment for the LNG vehicle, which including the service contract, is 60.9% higher than that of a diesel powered vehicle.

Taking into account the average return on LNG fuel that is made per each run kilometer being EUR 0.084, the break-even point for investments in LNG vehicle considering the above assumptions is reached for mileages exceeding 105,000 km per year. Then the monthly savings on LNG fuel will outweigh the other vehicle operating costs (TCO). As an example, for mileage of 120,000 km, the annual return on an LNG vehicle is EUR 1,573, compared to a diesel powered vehicle.

**LNG-powered vehicles offer many advantages**, the vehicles are environmentally friendly (lower emissions of particulate matter, nitrogen oxides and carbon dioxide), the fact that there is no need to use AdBlue additives, less noisy engine, lower consumption of cheaper fuel, and simpler design of the exhaust system contribute to greater reliability over a long period of time, and thus lower maintenance costs.

Limitations for LNG powered tractors at the moment include high purchase costs, lower engine power, limited range, poor in-

frastructure of refueling stations, a ban on entry in certain areas due to a gas drive system, and a low level of popularity of these vehicles on the market, which leads to a lower buy-back price and higher insurance compared to diesel powered vehicles.

The use of LNG fuel on a large scale in Europe represents an interesting alternative to diesel.

**Iveco Stralis AT 440S33 TP LNG** is a vehicle designed primarily for applications carrying up to 15 tonnes and annual mileages exceeding 105,000 km.

If you are considering purchasing, a number of factors must be taken into account that have a direct or indirect impact on investment profitability:

- Fuel prices,
- EUR exchange rates,
- Infrastructure of refueling stations,
- Type of roads that vehicles will drive on,
- Traffic conditions,
- Terrain slope,
- Vehicle technical condition,
- Energy-efficient driving techniques.

# 5 conditions for project success

| | |
|---|---|
| **Politicians**<br>**Legislators**<br>**Associations** | Stable transport policy<br>Medium- and long-term fuel fiscal policy<br>Support for development of infrastructure and research |
| **Manufacturers** | Available transport solutions<br>Wider product and service offer meeting customers' needs<br>100% tested and safe technology |
| **Fuel suppliers** | Investments in infrastructure |
| **Technology suppliers** | Technology availability |
| **Transport and municipal companies** | Testing the available transport solutions |

# Closing remarks

The use of alternative methane fuels, such as CNG, LNG and biomethane for vehicles means:

- zero particulate matter emissions,
- reduction of nitrogen oxides emissions,
- reduction of CO2 emissions,
- lower noise level than that of the diesel fuel engine - on average - 5 dB.
- 100% „tightness" when refueling

*„Liquefaction of natural gas provides a safe and economical alternative fuel for transportation. Ecological LNG fuel for buses and large commercial fleets makes it possible to reduce emissions and improve air quality in urban areas. LNG use as vehicle fuel has already been successful in some segments of the long-haul trucking industry. LNG infrastructure requires a joint effort of LNG suppliers, owners and station operators as well as potential owners of LNG vehicles. Cost-effective and sustainable development of LNG infrastructure requires careful selection of refueling station locations and making maximum usage of standard projects.*
*LNG as fuel for the transport sector provides a solution for environmental and economic issues. However, implementing alternative fuel usage means that heavy duty vehicle operators need to be provided with more information about availability of new eco-efficient drives in the automotive industry"* Bartłomiej Kamiński, President of the Green Fuel Foundation, said.




**Cryogas M&T Poland S.A.**
ul. Spokojna 5
01-044 Warszawa
tel. +48 22 439 01 00
e-mail. biuro@cryogas.pl

**IVECO Poland Sp. z o.o.**
Al. Wyścigowa 6
02-681 Warszawa
tel. +48 22 578 43 00
sekretariat.recepcja@iveco.com

CRYOGAS
M&T POLAND

IVECO
Twój partner w zrównoważonym transporcie