# *CHALLENGES FOR LARGE GAS ENGINES IN FUTURE ENERGY SYSTEMS*

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## Overview

Fluctuations in gas quality are a key aspect that comes along with the decarbonisation of the energy system. New sources of gas production push to be admissible into the gas grid. Biogas that is upgraded to biomethane introduces traces of a variety of gases, though. Future power-to-gas technologies will deliver additional shares of syngas or hydrogen to the gas distribution system. This will pose new requirements to gas engines. In special applications gas engines also have to cope with waste gases from industry, landfill gases and flare gases.

But also liberalization efforts for the European gas market give rise to gas quality fluctuations in today's gas grid caused by slightly different characteristics of the different pipeline gases which are available in Europe. The other source of varying gas fuel quality is the feed-in of LNG in (local) gas grids.

The research and development challeges that are linked with these trends for reciprocating gas engines are outlined in this paper. A specific focus is given to the influence of gas quality on component life expectancy. The LEC Development Methodology (LDM) is a means to deal with these complex requirements. It combines design strategies, sensor measurement data, statistical models and control strategies into a comprehensive methods for design and control of gas engines [Pirker et al., 2016, Schnessl et al., 2016].

## Methods

- Desktop analysis of the main sources of fluctuation and the implications on gas quality, European standards and regulation related to this topic
- Systematic of the gas quality influence on modern gas engines and description of characteristic parameters for the combustion behaviour of the engine as well as description of engine wear processes related to chemical and physical gas properties (e.g. of biogas and of $H_2$)
- Outline of the cornerstones of LEC's method to deal with those influences (LDM method)

## Results

Large gas engines in stationary operation are normally set for a specific gas. In Europe mostly the Russian gas or the natural gas form the North Sea are used. But gas quality cannot be expected to remain constant in future [Zelenka et al., 2017] due to shares of a rising variety of different sources. There is a necessity to exploit all sources of combustible gases in a manner that serves the energy system of the future and minimizes any environmental burdens, i.e. the greenhouse effect.

A study was performed that identifies the main gas characteristics relevant for an efficient and safe operation of a large bore gas engines. These are the Wobbe Index that is related to the energy content of the gas and the methane number that is related to the combustion behaviour in a reciprocating engine. For a variety of typical gas compositions (among these biomethane, biogas, LNG and Hydrogen) the gas characteristic properties are calculated and correlated to the valid gas standards. By mixing 100% Russian gas with landfill gas and anaerobic digester gas, the calorific value decreases but not so much that it will fall below the relative density limit. The value of reaching the admissible limits of the Wobbe Index of the relevant standards EASEE and ÖN EN 16726:2016 were found to be 22 mol% (EN 16726) respectively 15 mol% (EASEE) for a biogas with a typical composition of 63% methane and 37% $CO_2$ (only the shares of gases contributing to calorific value). The correspondent values of landfill gas were 28 mol% (EN 16726) and 19 mol% (EASEE) when taking a typical mixture of 45% methane, 1% $O_2$, 14% $N_2$ and 40% $CO_2$. For admixing of $H_2$ the calorific value decreases rapidly and so the relative density limits is below those of both standards EN 16726 and EASEE even for less than 5% $H_2$. The methane number which is the most important variable concerning the knocking behaviour of a reciprocating engine of all mixtures were also calculated. Calculation was performed according to five different methods and gave an average of round 100 for biogas as well as landfill gas which is almost the same value as pure methane and does not pose any risk of knocking. The admixing of $H_2$ decreases the methane number, however $H_2$ poses high demands on engine operation that cannot be described solely by the methane number.

Furtheron gas mixtures with a high share of aggressive components and contaminants, e.g. biogas from waste and manure fermentation, give rise to damages of recipropating engines. As the most important fuel-gas related hardware sensitivity phenomena the following have been recognized: Corrosion, deposits/fouling, ageing (of the lube oil) and tightness (in engines powered by hydrogen).

The most aggressive acting component in the fuel gas are sulphur compounds. Biogas contains often a significant amount of $H_2S$. Reactions of the engine oil with biogas and landfill and sewage gas reduce the alkaline oil reserve, the main component of lubricant oil ageing. In addition landfill and sewage gases cause severe deposit problems in an engine that are connected to the siloxanes in the gas stream. This is known for quite some time, but obviously depending on combustion parameters (mainly the temperature and pressure) also more complex structures have been reported [Surita et al., 2015, Alvarez-Florez et al., 2015]. Major challenges occur for reciprocating engines when they are fuelled by a hydrogen-rich gas.

If the gas composition varies during engine operation, operating parameters normally have to be changed. This is to protect the engine components on the one hand (knocking combustion) and to comply with emission regulations while maintaining required load and optimum efficiency on the other hand. In the figure 1 we describe in which engine development stages gas variables have an important influence and therefore have to be considered in the concept design of gas engines. The standard LDM-method relying mainly on steady-state combustion concept development (CCD) is extended to an advanced model (LDM Advanced) incorporating several more issues [Pirker et al., 2016].

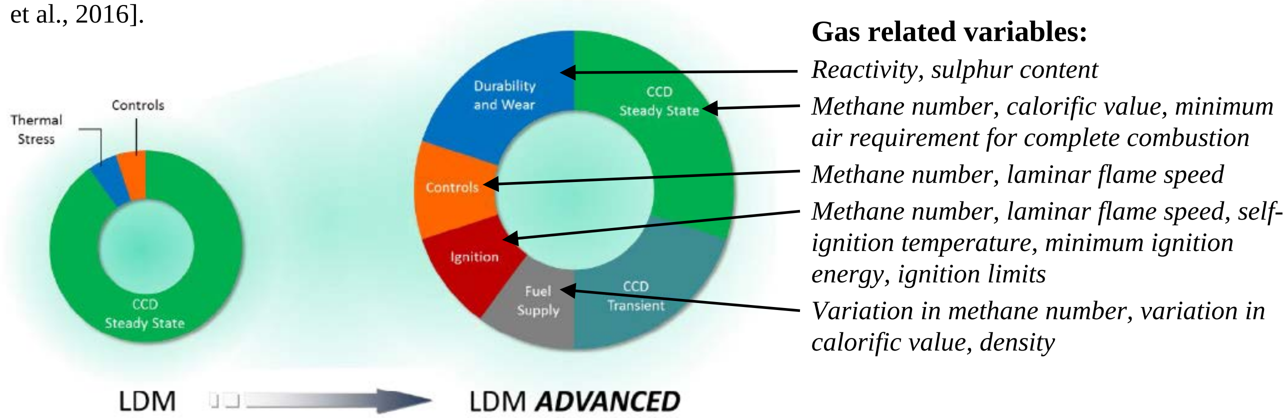


Fig. 1: Progress from State-of-the-art development methodology (LDM) to Advanced LDM Methodology capable of integrating detailed gas quality parameters

## Conclusions

From the environmental point of view, gas engines are a key factor in power generation due to their comparatively low environmental impact (emissions), which is further enhanced by the great progress in terms of efficiency and power output that have been achieved in recent years. This performance can be reached by advanced methods of engine development that take into consideration varying gas parameters.

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