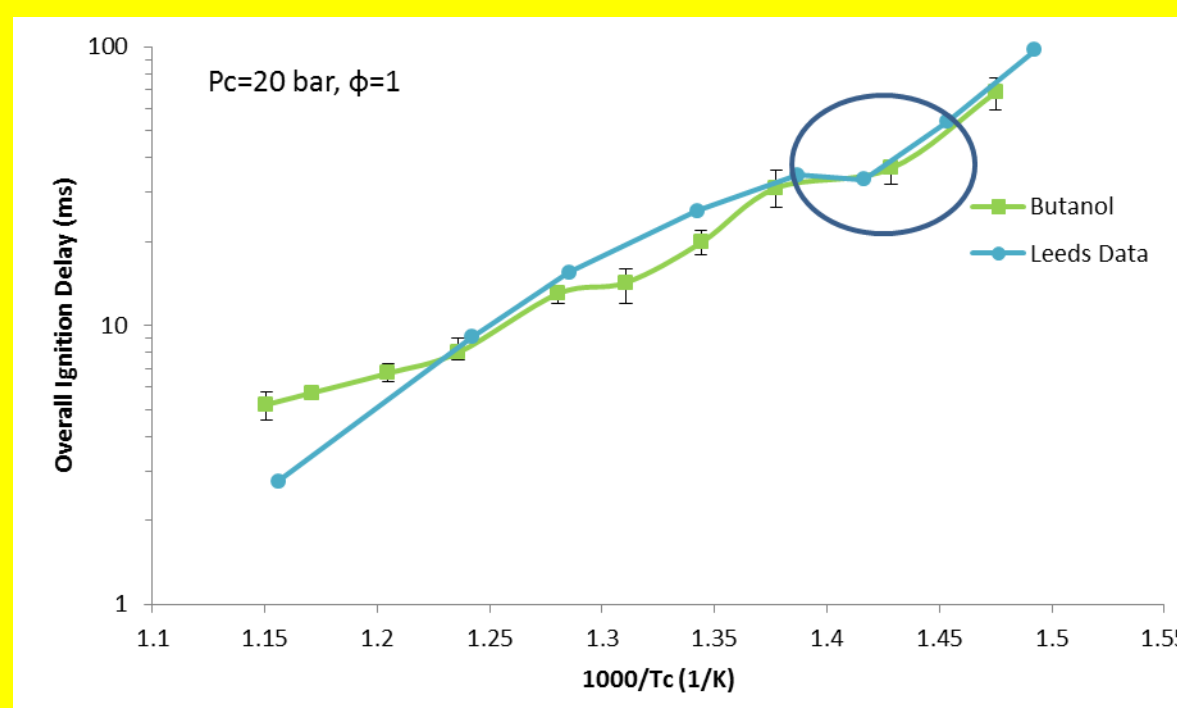


## 1. Aims of the Project

- In the UK, the transport sector accounted for 36% of total energy consumption in 2013 (DECC, 2014), and was responsible for 21% of greenhouse gas emissions for the same year (DECC, 2015). Road transport also accounted for 18 percent of particulate emissions (PM2.5 and PM10) in 2013 (DEFRA, 2014). The climate change act was enacted by the UK government in 2008, which states a target of 80% reduction in greenhouse gas emissions by 2050 (IoG, 2012).
- Combustion-based engines are currently the only feasible technology that can offer an immediate solution to the energy demands of the world on a large scale.
- The continued use of fossil fuels also raises questions of sustainability and energy security in the future and as a result, alternative fuels are a significant area of current research. Biofuel is one such avenue of research that offers promise.
- However, biofuels present a number of challenges. The combustion properties of biofuels may have significant differences when compared to currently used fuels such as gasoline and diesel.
- Modelling of new engines and fuels is crucial: models can be used to accurately predict the feasibility of new engine technologies and fuels before undergoing costly practical testing and experiments.
- In order to produce accurate models, it is of importance that the combustion properties of these fuels are well understood. This raises a complex problem that gasoline cannot be modelled due to the thousands of hydrocarbons so similar fuels are used to represent gasoline; known as surrogates, but how well will a surrogate represent gasoline when blended with a biofuel?

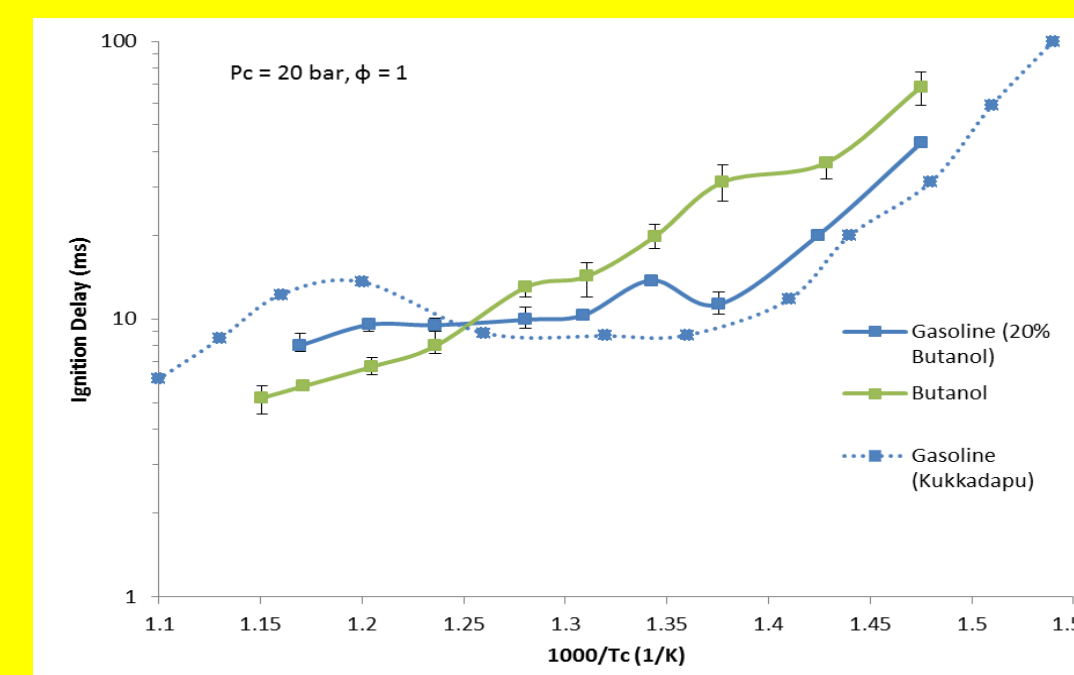
## 3. Results



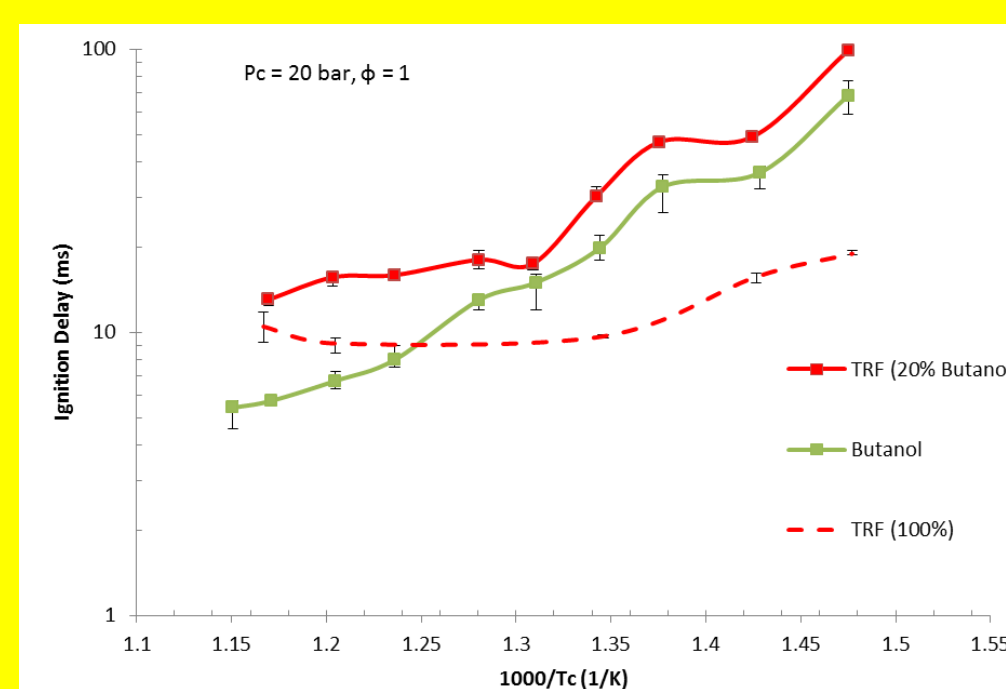
Ignition delay times for butanol mixtures corresponding to Table 3.2, compared with previous work undertaken on the same RCM at Leeds University (Materogo, 2014).

- The secondary data which has been included on this graph is from a previous study conducted at the University of Leeds for similar conditions using the same RCM machine (Materogo, 2014).
- As the temperature increases there are a shortened ignition delay times
- Repeatability of the experiment appears to show a certain degree of validity
- Another feature area, which is circled on the graph, supports this validation. It appears not only in this project's data and the previous study, but also further afield demonstrated by Weber et al. (2011).

- Being a blend it is expected that the ignition delays would lie in between the unblended, which it does for both the lower and higher temperatures.
- The unblended gasoline experiences a negative temperature coefficient region in the higher temperature region
- There is no negative temperature coefficient for butanol, which has also been seen in previous studies (Weber et al., 2011).



Comparison of ignition delays between blended butanol and unblended butanol and gasoline



Comparison of unblended TRF and butanol with blended TRF

- The butanol appears to have a drastic effect upon the TRF surrogate once blended.
- Both sets of results show similarities at certain points, with a levelling off of ignition delay times as higher temperatures (>750K) are reached,
- The ignition delay times themselves are much different. Blending this particular TRF with butanol causes the reaction mechanisms during combustion to change.

## 2. Methodology

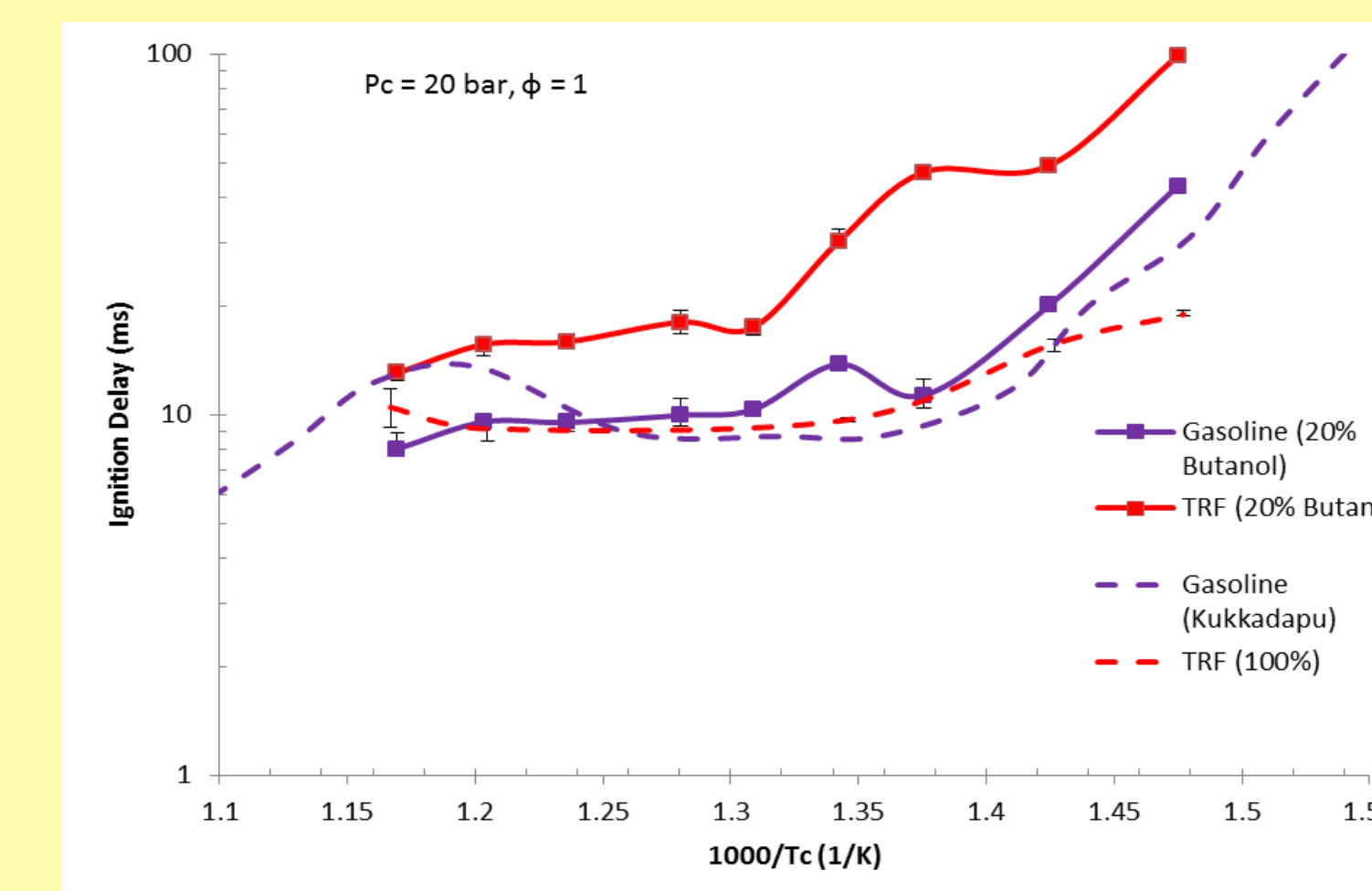
Testing the feasibility of a blended biofuel-surrogate and blended biofuel-gasoline mixture was tested in a Rapid Compression Machine (RCM) through:

- Measuring the auto-ignition delay times for unblended butanol
- Compare surrogate mixture ignition delay times with reference gasoline
- Compare ignition delays of gasoline blend with 20% butanol to surrogate blend with 20% butanol

A range of temperatures were chosen based on previous work from the University of Leeds and Weber et al. (?)

The surrogate used for these experiments is a combination of toluene, n-heptane and iso-octane; more commonly known as a TRF. Properties of the reference gasoline were provided from Shell and then used to calculate the % volumes needed for the TRF. In order to assess the blend ratios reactive and nonreactive runs were performed on the butanol to ascertain the volume history of the RCM which evaluates the heat loss used to find the blend ratio.

## 4. Discussion



- Both the gasoline and the TRF show distinctive features and behaviours, individually and when compared together.
- The gasoline shows a continuous improvement in its ignition delay times, but at around 800K it begins to experience a negative coefficient region because of the reversibility of the addition of radicals to O<sub>2</sub> molecules.
- The ignition delay for the gasoline blend appears to have no dependence upon temperature in this range, which would indicate that it has a balance of the unblended gasoline and butanol properties in near equal proportions.
- As the unblended gasoline begins to experience a positive temperature coefficient once more as does the blend, which would be expected as this is also happening with the unblended butanol.

- It would be expected that a combination of the two fuels would result in ignition delay times somewhere between the two components
- These results imply that blending the TRF and butanol actually results in a mixture that has longer ignition delay times than either separate component has over the same range of temperatures.
- The TRF reacts very differently in response to blending with butanol, in comparison with the reference gasoline.
- Ignition delay times of the unblended gasoline and TRF closely match, while the blended fuels show significant differences in behaviour.
- There are variations in the complex cross-reactions that occur during compression and ignition between the unblended and blended fuels
- Butanol oxidation at low temperature regimes is facilitated by radical pool generated through the oxidation of n-heptane
- The oxidation of iso-octane at low temperatures may be inhibited, should a radical pool not be available through other reactions, by the presence of toluene which acts as a radical scavenger

## 5. Conclusion

- The TRF appears to be a good reference for gasoline when unblended
- TRF and gasoline react very differently in response to butanol blending
- This suggests a three-component surrogate may not be sufficient in representing the complex cross-reactions that result from blending

### References:

- DECC 2014. Chapter 1: Overall energy consumption in the UK since 1970. *Energy Consumption in the UK*.  
 DECC 2015. 2013 UK Greenhouse Gas Emissions, Final Figures. *Final UK greenhouse gas emissions national statistics*.  
 DEFRA 2014. Emissions of Air Pollutants in the UK, 1970 to 2013. *National Statistics Release*.  
 IOG 2012. The Climate Change Act (2008). Institute of Government.  
 MATEROGO, M. 2014. *Autoignition characterisation of synthetic fuels via rapid compression machine (in preparation)*. PhD, University of Leeds.  
 WEBER, B. W., KUMAR, K., ZHANG, Y. & SUNG, C.-J. 2011. Autoignition of n-butanol at elevated pressure and low-to-intermediate temperature. *Combustion and Flame*, 158, 809-819.