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Transport and Climate Change: Reasons, Resources, Responses

While federal politicians argue over who has the best climate change policy and scientists continue to refine the climate change science and warnings, transport professionals are left wondering what it means for them, and how they should respond to the climate change challenge. This forum explores the reasons for climate change, some climate-friendly technologies already available, and policy responses relevant to the transport sector.

OPTIMISATION OF DUAL FUEL (ETHANOL-DIESEL) ENGINE

QUT

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Acknowledgements

- Alternative Energy Technologies P/L
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Presentation Outline

- Background
- Introduction to Engines
- Introduction to Dual Fuel Systems
- Proposed Dual Fuel System
- Research Approaches
- Conclusions

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Background: Liquid Fuel Alternatives

- What can serve as an alternate fuel?
  - Alcohol (Ethanol, Methanol)
  - Vegetable oil
  - Liquefied Petroleum Gas (LPG)
  - Compressed Natural Gas (CNG)
  - Liquefied Natural Gas (LNG)

Fuel Prices in Brisbane

	Calorific Value (MJ/kg)	Nov 2006	Dec 2006	Jan 2007	Feb 2007	Mar 2007	Apr 2007	May 2007	Jun 2007
Unleaded	47.3	108.1	110.9	109.1	107.8	117.5	119.5	123.8	122.5
Premium	47.3	116.3	103.7	116.5	114.4	126.2	127.0	131.1	130.1
Diesel	44.8	116.7	112.7	116.1	114.5	116.1	119.7	121.2	122.4
LPG	49.9	52.6	41.9	54.5	53.7	53.2	54.4	54.7	54.3
Ethanol	29.7			107.9	106.2	116.3	119.0	122.9	121.3

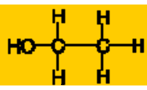
http://www.racq.com.au/cps/rde/xchg/racq_cms_production/hs.xsl/News_Fuel_Prices_Foun_news_fuel_pricereports_ENA_HTML.htm

Dual Fuel Systems

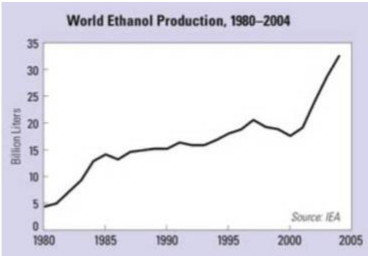
- Fumigation
  - Addition of secondary fuel to the intake air charge
  - Displacing up to 50% of the diesel fuel demand
- Dual injection
  - Separate injection system with control for each fuel
  - Displacing up to 90% of diesel engine demand
- Blend Fuel
  - Mixture of the fuel just prior to injection
  - Displacing up to 25% of diesel engine demand
- Fuel Emulsion
  - Mixture of the fuel by using emulsifier
  - Displacing up to 25% of diesel engine demand

Quoted from Abu-Audais, et al., *Energy Conversion & Management* 2000

Ethanol



- Ethyl alcohol (C_2H_5OH)
- Production of Ethanol
  - Carbohydrate-rich plants
  - Ligno-cellulosic products



Ethanol yield from carbohydrate-rich plants

Raw material	*Carbohydrate (t/ha)*	*Carbohydrate %*	*Ethanol (l/t)*	*Ethanol (hl/ha)*
Beet	40–60	16	90–100	38–48
Sugar cane	50–100	13	60–80	35–70
Maize	4–8	60	360–400	15–30
Wheat	25	62	370–420	8–20
Barley	2–4	52	310–350	7–13
Grain sorghum	2–5	70	330–370	7–18
Potatoes	20–30	18	100–120	22–33
Sweet potato	10–20	26	140–170	16–31
Cassava	12–15	27	175–190	22–23
Jerusalem artichoke	30–60	17	80–100	27–54

Table 5.3b *Ethanol yield from ligno-cellulosic products*

Raw material	*(hydrolytic agent)*	*Dry matter (t/ha)*	*Ethanol (l/t)*	*Ethanol (hl/ha)*
Softwood	(dilute acids)	9–15	190–220	18–31
	(concentrated acids)	9–15	230–270	22–38
Hardwood	(dilute acids)	9–15	160–180	15–25
	(concentrated acids)	9–15	190–220	18–30
Straw	(dilute acids)	1.5–3.5	140–160	2–5
	(concentrated acids)	1.5–3.5	160–180	3–6

http://www.rise.org.au/info/Applic/Ethanol/index.html

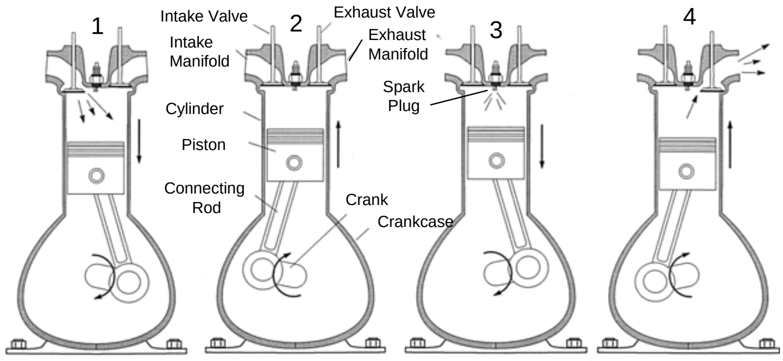
Ethanol Fuel

- Application of Ethanol
  - Gasoline blend (5 – 10%)
  - Diesel blend (E-diesel)
- Characteristic of Ethanol
  - Lower volumetric energy content
  - High octane rating
  - result in increased engine efficiency and performance
- Environmental characteristics
  - Produced "renewably"
  - Reducing greenhouse gas emission

Introduction to Engine

- External combustion
  - combustion of an air-fuel mixture transfers heat to a second fluid which becomes the motive (working) fluid that produces power
  - E.g., steam driven engine
- Internal combustion
  - the products of combustion are the motive fluid
  - Spark ignition (SI) engines
    - a compressed, homogeneous air-fuel mixture (15:1 ratio of air to fuel by mass) is ignited using a spark
    - Petroleum (high octane rating) is used
  - Compression ignition (CI) engines
    - rapid compression of air to a high pressure raises the temperature so that fuel, when delivered into combustion chamber, spontaneously ignites without need for a spark
    - often referred to as a Diesel engine
    - Diesel fuel (high cetane rating) is used

Four Stroke Engine



Intake Stroke
Intake valve opens, admitting fuel and air. Exhaust valve closed for most of stroke

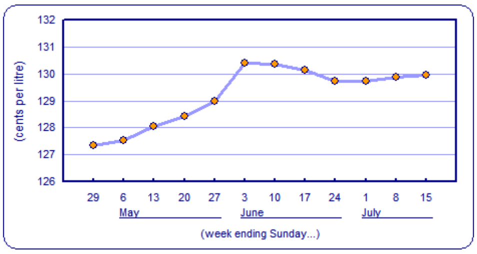
Compression Stroke
Both valves closed, Fuel/air mixture is compressed by rising piston. Spark ignites mixture near end of stroke.

Power Stroke
Fuel-air mixture burns, increasing temperature and pressure, expansion of combustion gases drives piston down. Both valves closed - exhaust valve opens near end of stroke

Exhaust Stroke
Exhaust valve open, exhaust products are displaced from cylinder. Intake valve opens near end of stroke.

Introduction to Dual Fuel Systems

- Why use dual fuel?
  - Transition technology
  - Fossil (non-renewable) resource
  - Diesel price
  - Particle and No_x emission
    - Higher combustion temperature than Petroleum
  - Greenhouse gas emission



Average Weekly Diesel Fuel Prices for the 12 Weeks to Sunday, 15 July 2007
- National Average -
http://www.aip.com.au/pricing/retail/diesel/index.htm

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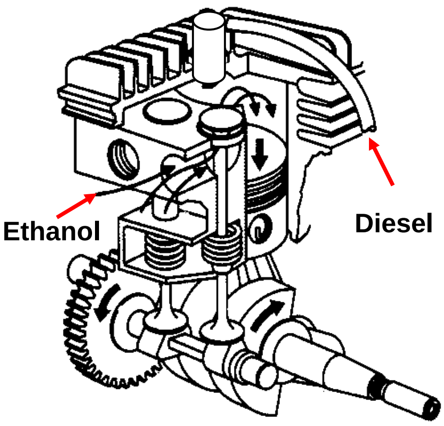
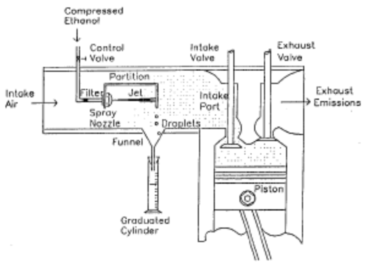
Introduction to Ethanol fumigation System

- Pilot Fuel
  - Injected from spray nozzle
  - Reliable and instant ignition
    - High cetane, diesel fuel
- Supplemental Fuel
  - Injected through air-intake
  - Long and slow combustion
    - High octane, ethanol
- Advantage
  - Minimum modification needed
  - Ethanol fuel is separate from the diesel system, no mixing needed
  - Ethanol could reduce smoke
  - Fumigation can substitute ethanol for 50% diesel fuel

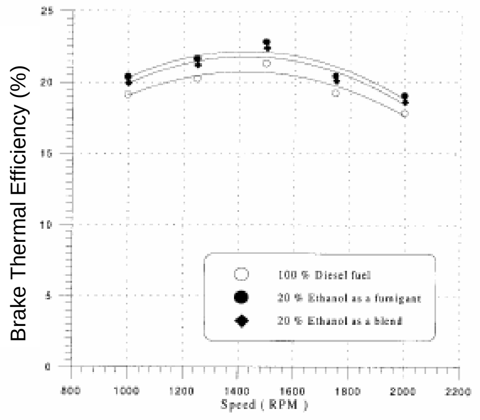


Comparison between Fumigation and Blend

- Comparison Test (Abu-Qudais et al. 2000)
  - Single cylinder, four storke, direct injection diesel engine
  - Swept volume 0.582 litre

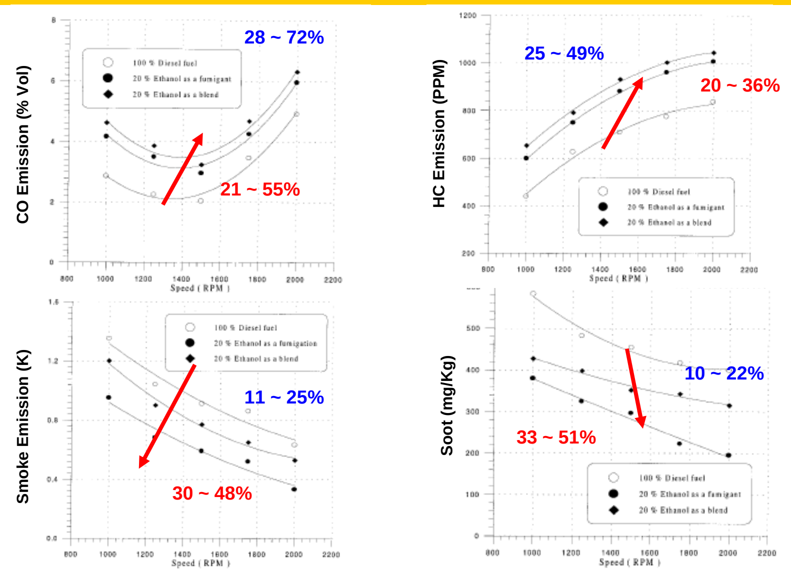


Ethanol Fumigation System



- Slight improvement in the efficiency
  - 7.5% for 20% ethanol fumigation
  - 5.4% for 20% ethanol-diesel fuel blends

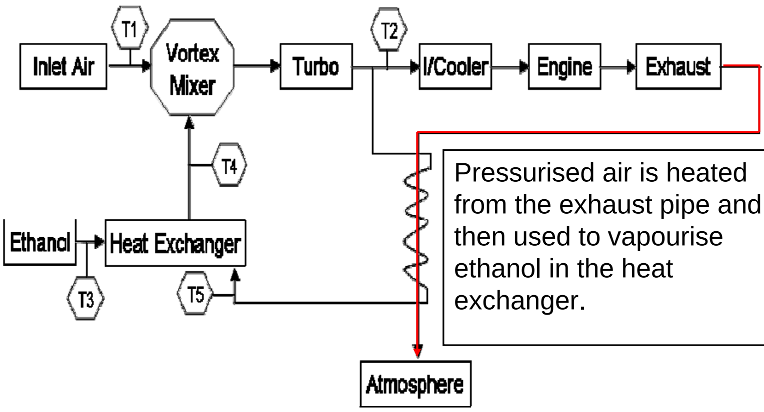
Emission Comparison between Fumigation and Blend



Dual Fuel System Research Team

Mr Uli Kruger, the inventor

Schematic Diagram of the Ethanol fumigation System



Pressurised air is heated from the exhaust pipe and then used to vapourise ethanol in the heat exchanger.

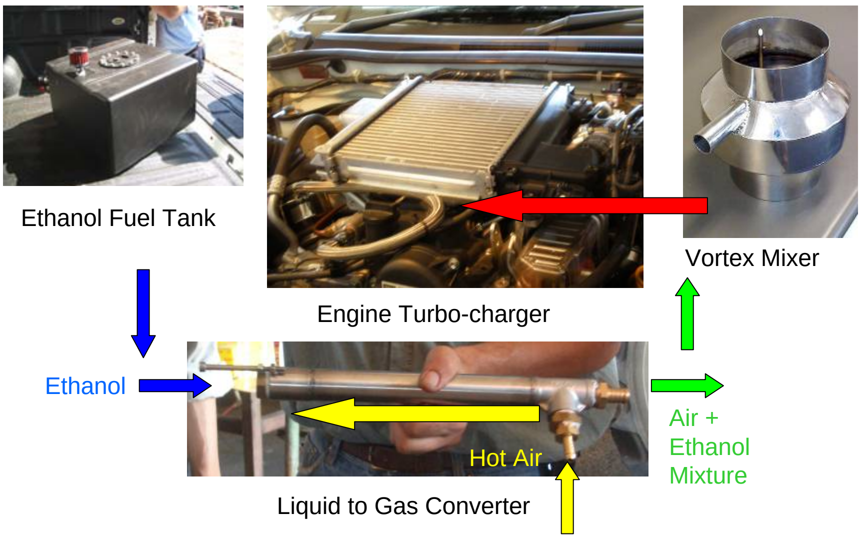
Ethanol fumigation System

Toyota Hilux 3 Liters 6 cylinder Diesel

6 Cylinder Engine

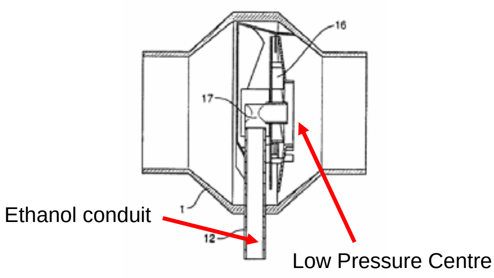
Ethanol Fuel Tank

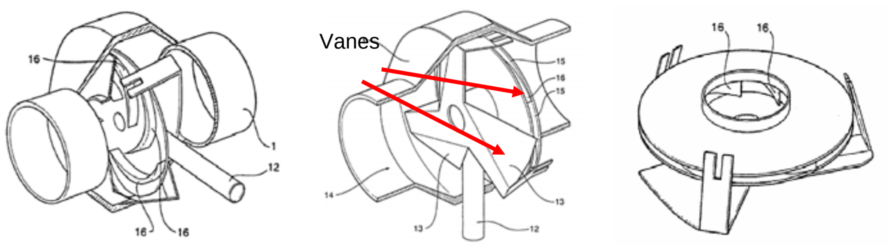
Ethanol fumigation System (Continued)



Natural Vortex Mixer

- Also called Centripetal Vortex, inward directed spiral
- Feature: low pressure at centre
- Can provide significant reliability in respect of air-fuel ratio over a reasonable load range





Dual Fuel System Test Run

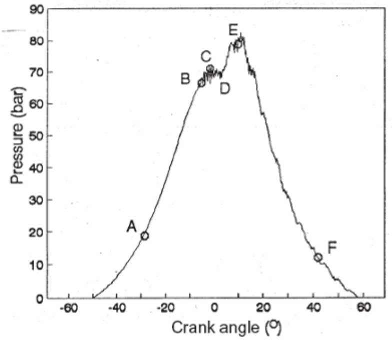
- Test Parameters
  - Engine: Perkins T4-236
  - 52 kW generator
  - 3000 rpm
  - Displacement: 3.86 liters
  - Compression ratio: 16:1
  - Supplemental fuel: LPG
- Test Result
  - Relative consistency in the diesel power ratio over total power
  - LPG mass percentage keep constant over the range of power outputs.
  - Significant reduction in No and smoke
  - Marginal drop in overall thermal efficiency

LOAD kW	time/ 200 mls	kW of Diesel kW	mass of LPG kg	kW of LPG kW	Effi- ciency %	Diesel Mass reduc %	Energy ratio Diesel/ Total
20	109	64.7	0	0	30.9	100	1.00
20	214	33.0	0.284	61.4	21.2	49.1	0.35
30	77	91.6	0	0	32.7	100	1.00
30	168	42.0	0.254	70.0	26.8	54.2	0.37
40	59	119.6	0	0	33.5	100	1.00
40	125	56.4	0.192	71.1	31.4	52.8	0.44

LOAD kW	CO2 %	CO2 reduc %	NO ppm	NO reduc %	Opacity	Opacity red %	AFR	HC
20	6.23		366		16		34.2	0
20	5.8	6.9	221	39.6	4	75.0	30.5	
30	8.18		645		34		26.6	0
30	7.47	8.7	400	38.0	14	58.8	26.3	
40	8.71		938		50		22.7	0
40	7.88	9.5	553	41.0	33	34.0	23.3	202

Research Approaches

- 1. Developing a framework for dual fuel engine evaluation
  - Multivariate analysis
    - Optimum engine operating parameter
    - Dual fuel/water ratio
  - Objectives
    - Reduce environmental emissions
    - Maximize power output and performance
- 2. Thermodynamic modeling
  - Modeling of dual fuel fumigation system
  - Modeling of diesel engine
    - Premixed ethanol fuel
    - Addition of water to the substitution fuel



Dual fuel pilot injection pressure-crank angle diagram
AB: pilot ignition delay (AB)
BC: pilot premixed combustion (BC)
CD: primary fuel delay period (CD)
DE: rapid combustion of primary fuel (DE)
EF: diffusion combustion stage (EF)
(After Nwafor, 2002)

Research Approaches (Continued)

- 3. Laboratory optimization, performance and emission testing
  - Engine performance testing
    - Throttle setting of 20, 40, 60, 80, and 100%
    - Dueal fuel ratios of "low", "medium", and "high"
    - Water ratio of "low", "medium", and "high"
    - 3 repetitions for statistical stability
  - Laboratory fuel/water optimization and performance testing
    - Engine performance over the full range of operating parameter
    - Primary measurement: brake power, peak and mean effective pressure
  - Emission testing
    - Gaseous emission: CO, CO_2, NO_x, and unburned hydrocarbons (HCs)
    - Particulate emissions, using mini dilution system and Scanning Mobility Particle Sizer (SMPS)
  - Standard industry 200 hour test
- 4. Identifying optimal engine/fuel parameter
  - Achieve optimal engine performance without significant increase of emissions
  - Application of after-treatment technologies possible
  - Elimination of knock (pre-ignition)
- 5. Field testing
  - Dalby City Council
  - Rocky point sugar Mill
- 6. Transfer of knowledge

Engine Performance Testing

Timeline

2007 2008 2009

Table 1: Project Schedule		Year 1				Year 2				Year3			
Module 1	1.1 Framework for dual fuel engine evaluation	■	■	■	■	■	■	▒	▒	▒	▒		
	1.2 multicriteria decision making				■	■	■						
	1.3 elimination of redundant parameters						■	■					
Module 2	Thermodynamic modelling												
	2.1 Consolidation of Teakle (2004) model		■	■	■								
	2.2 Comparision with other models eg Dibble et al , 2001				■	■	■	■					
	2.3 Investigation of engine characteristics, knock, efficiency						■	■	■	■	■		
	2.4 Modelling of emissions: gaseous and particulate						■	■	■	■	■		
Module 3	Laboratory performance and emission testing												
	3.1 Engine performance testing			■	■	■	■						
	3.2 Laboratory fuel/water optimisation and performance testing				■	■	■	■					
	3.3 Emission testing					■	■	■	■				
	3.4 Standard industry 200 hour test						■	■					
Mod 4	4. Identifying optimal engine/fuel parameters							■	■				
Mod 5	5 Field testing								■	■	■		
Mod 6	6 Transfer of knowledge			▒	▒	▒	▒	▒	▒	▒	▒	▒	▒

Conclusions

- Dual fuel systems were introduced
- Ethanol fumigation method was proposed
- Preliminary test show that this method with a natural vortex mixer can achieve consistent alternate fuel ratio over large load ranges
- Extensive rigorous research will be conducted to reach optimum performance