

# Hydrogen Powered Vehicles for Road Transport

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## FOSSIL FUEL RESERVES

(Proven reserves based on current production)

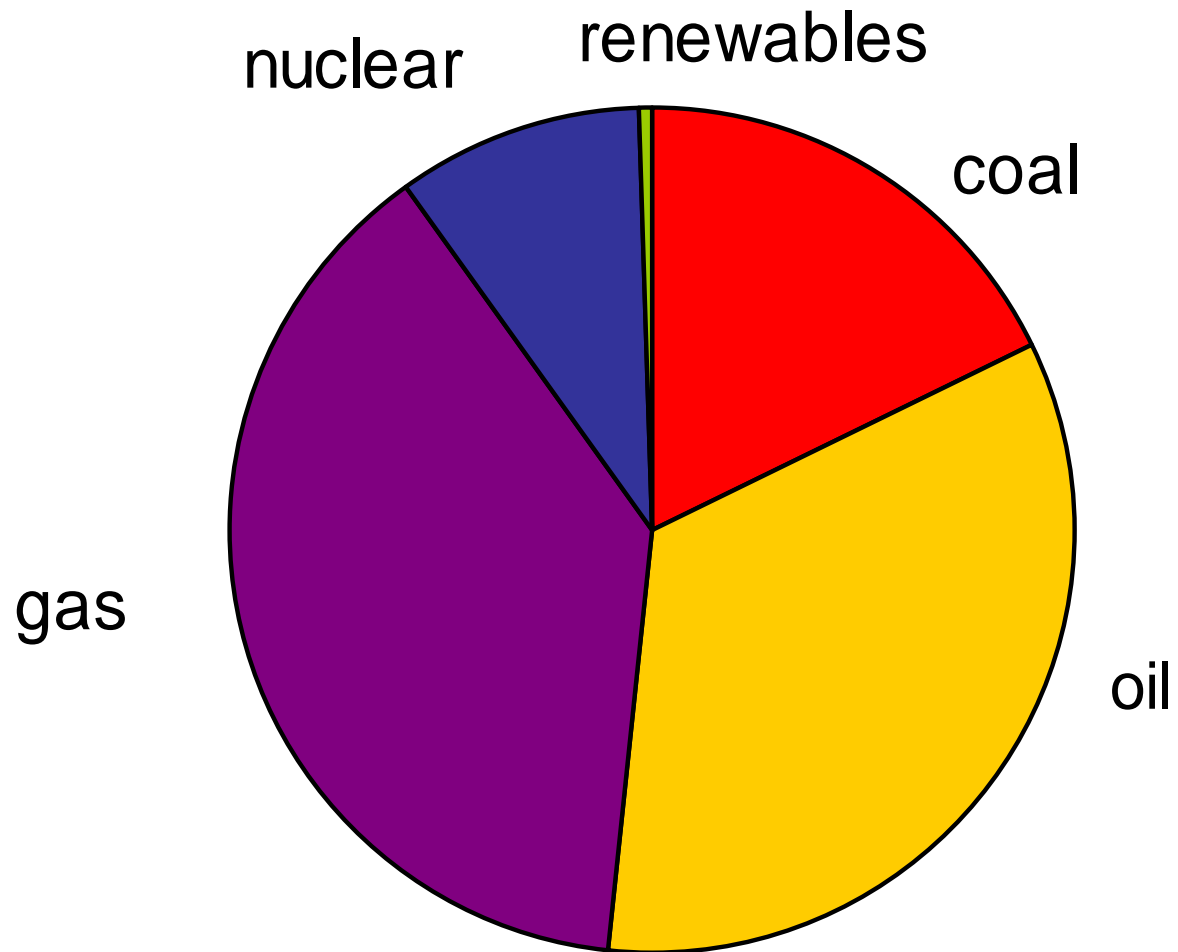
Coal: 164 years

Gas: 67 years

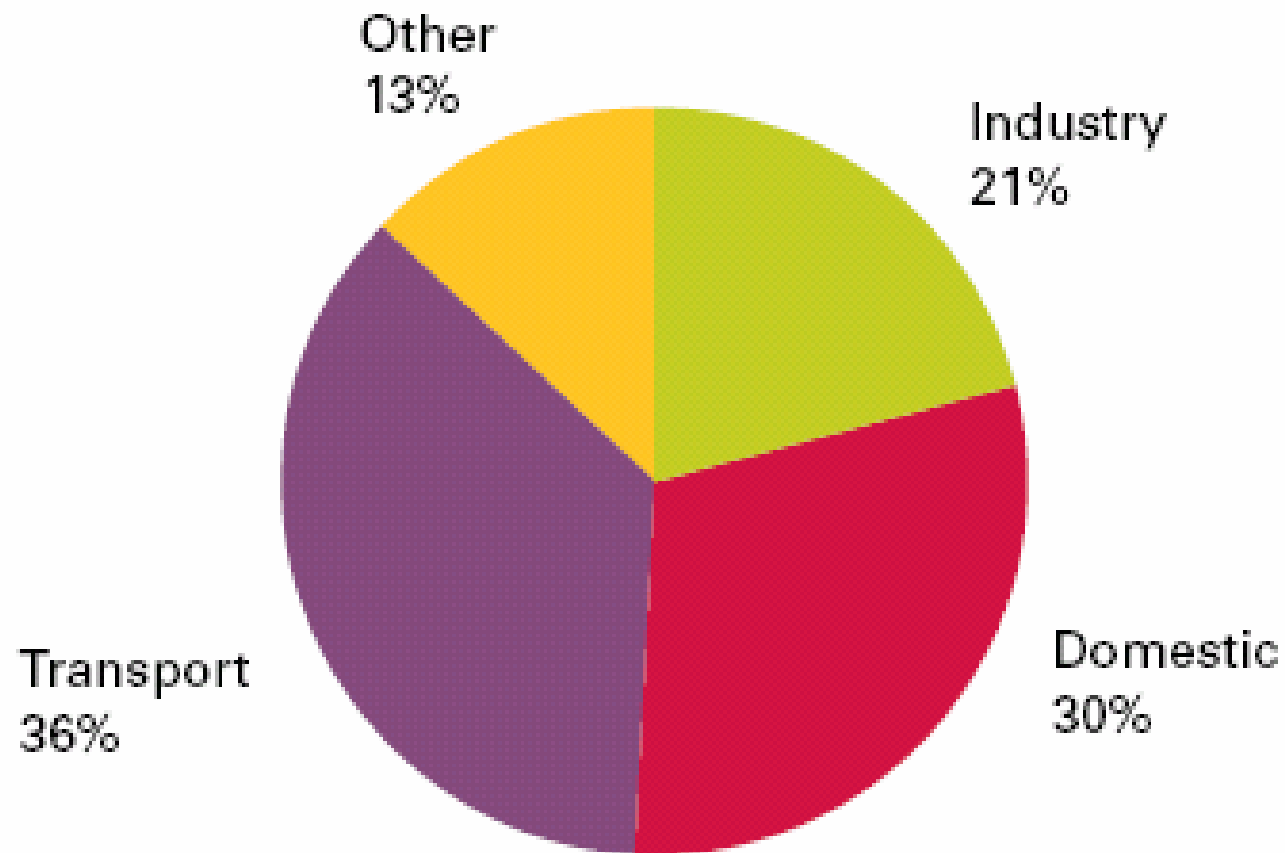
Oil: 41 years

(Source: World Coal Institute)

# UK Energy Consumption

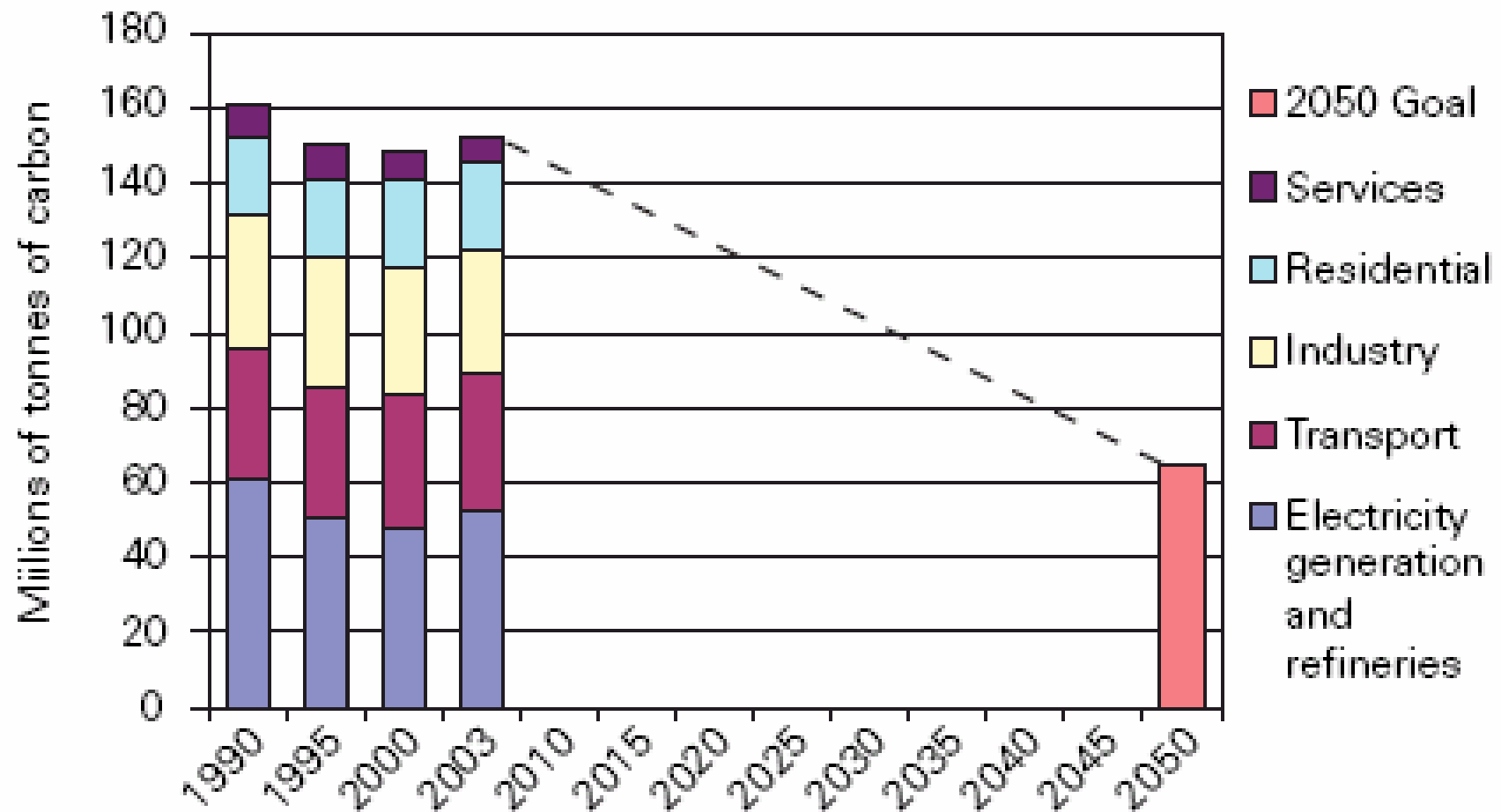


## End use of energy by sector of the economy in 2004



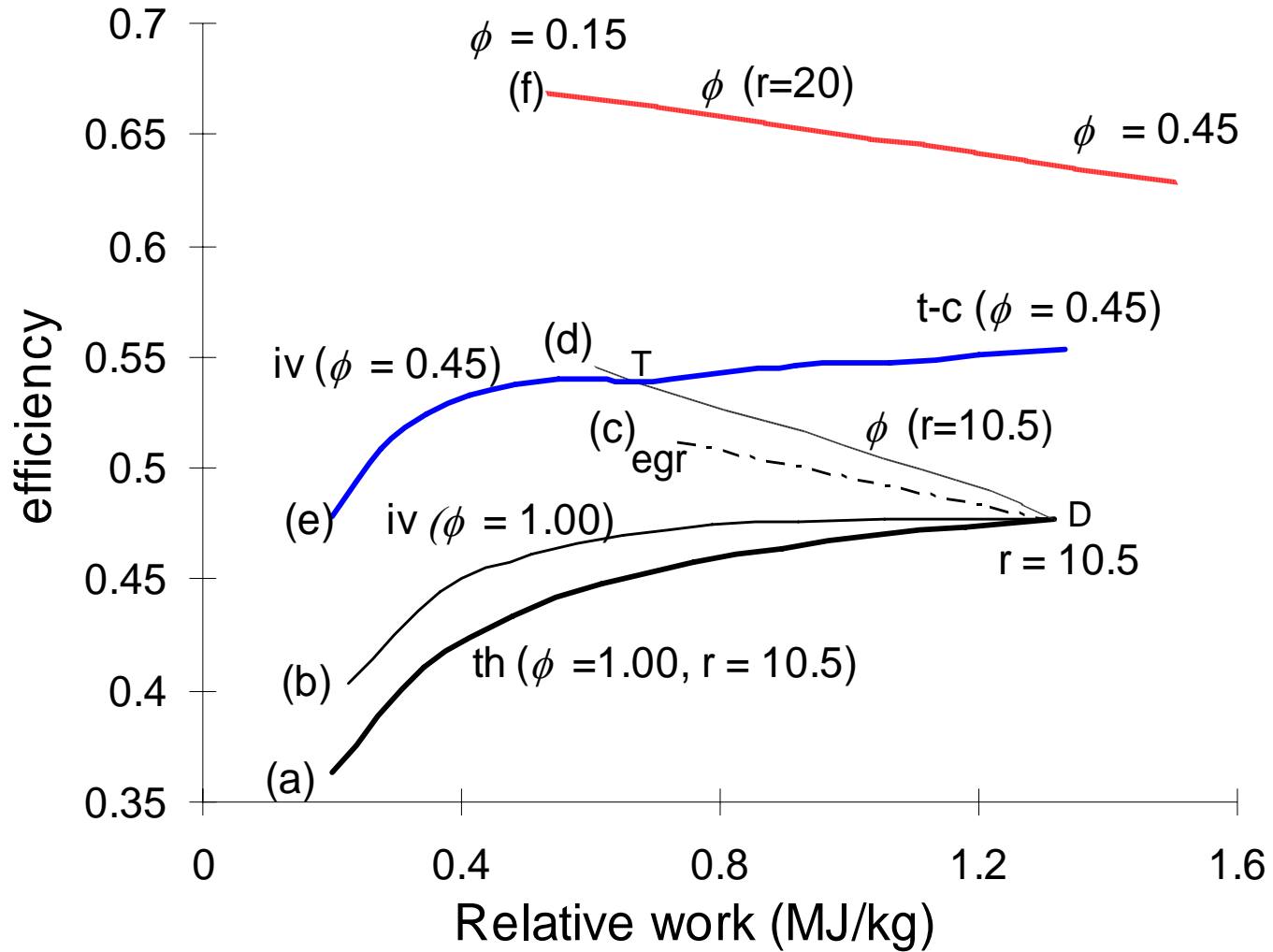
Source: DTI, DUKES 2005

## Carbon emissions by sector and the 2050 goal

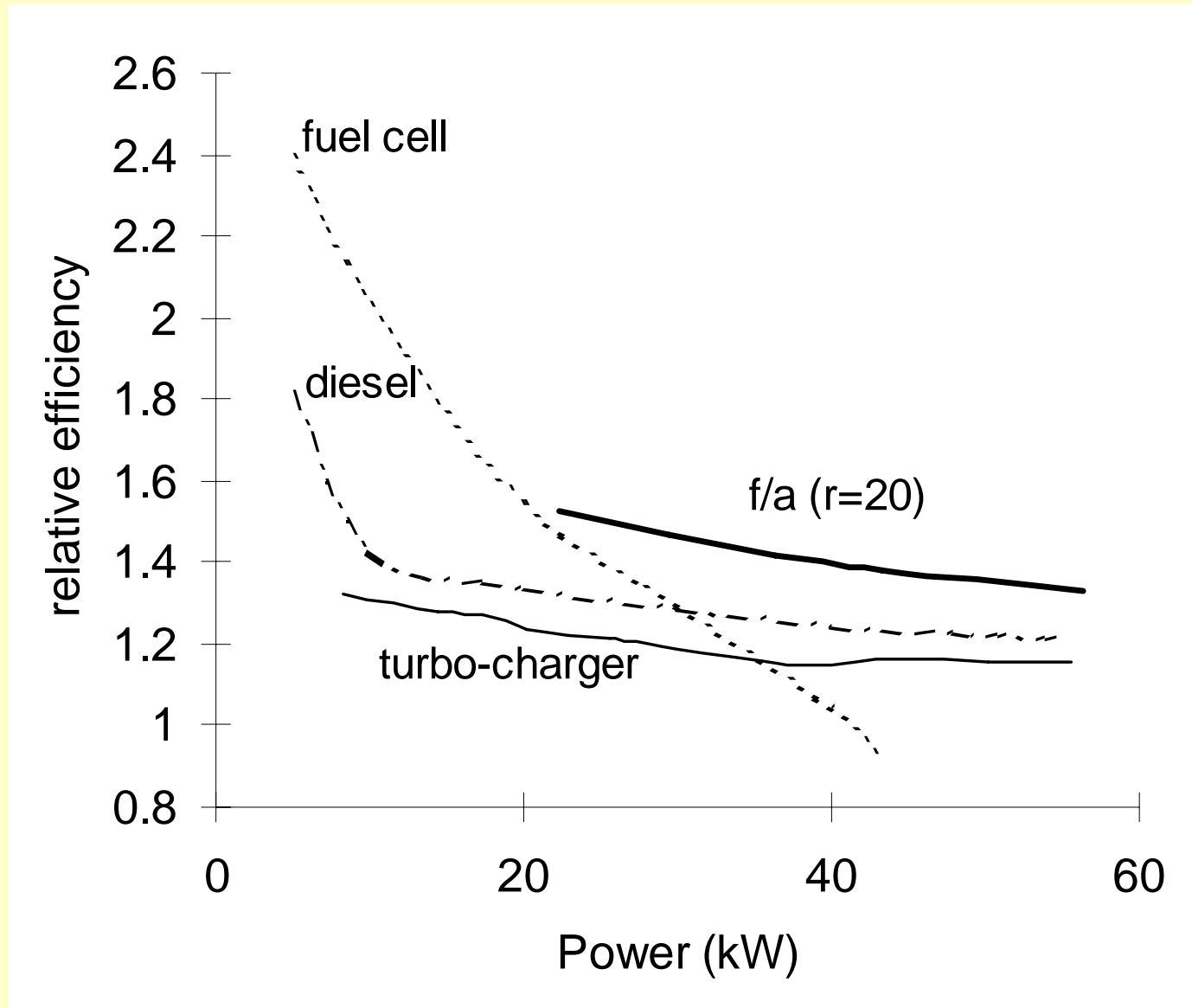


Source: DTI

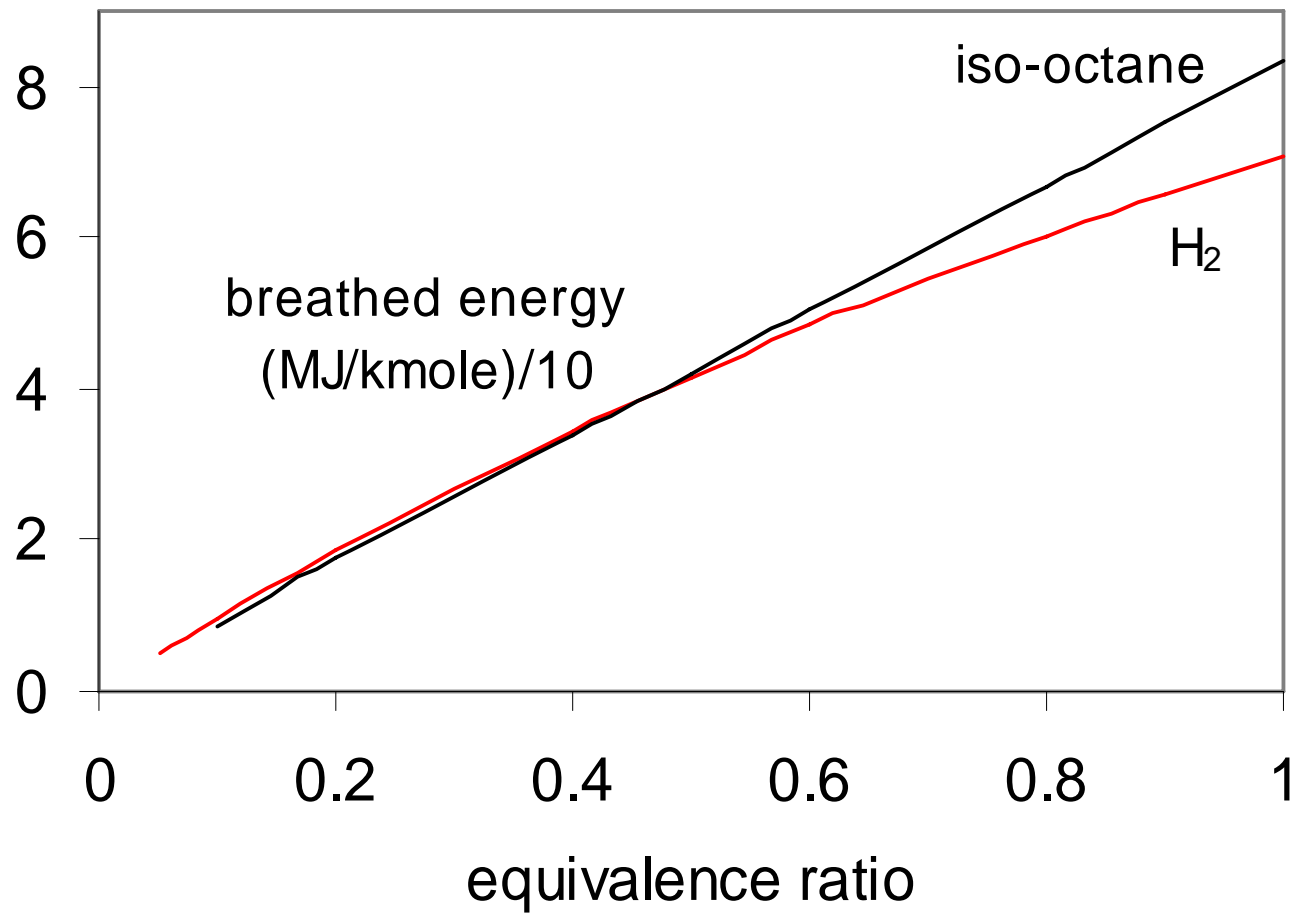
# Otto Cycle Efficiencies



# Practical Cycle Efficiencies

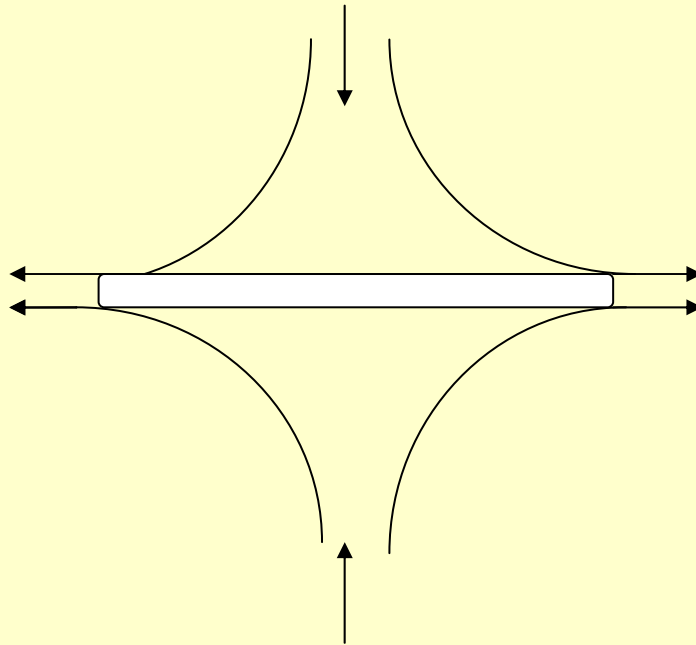


# Breathed Energy

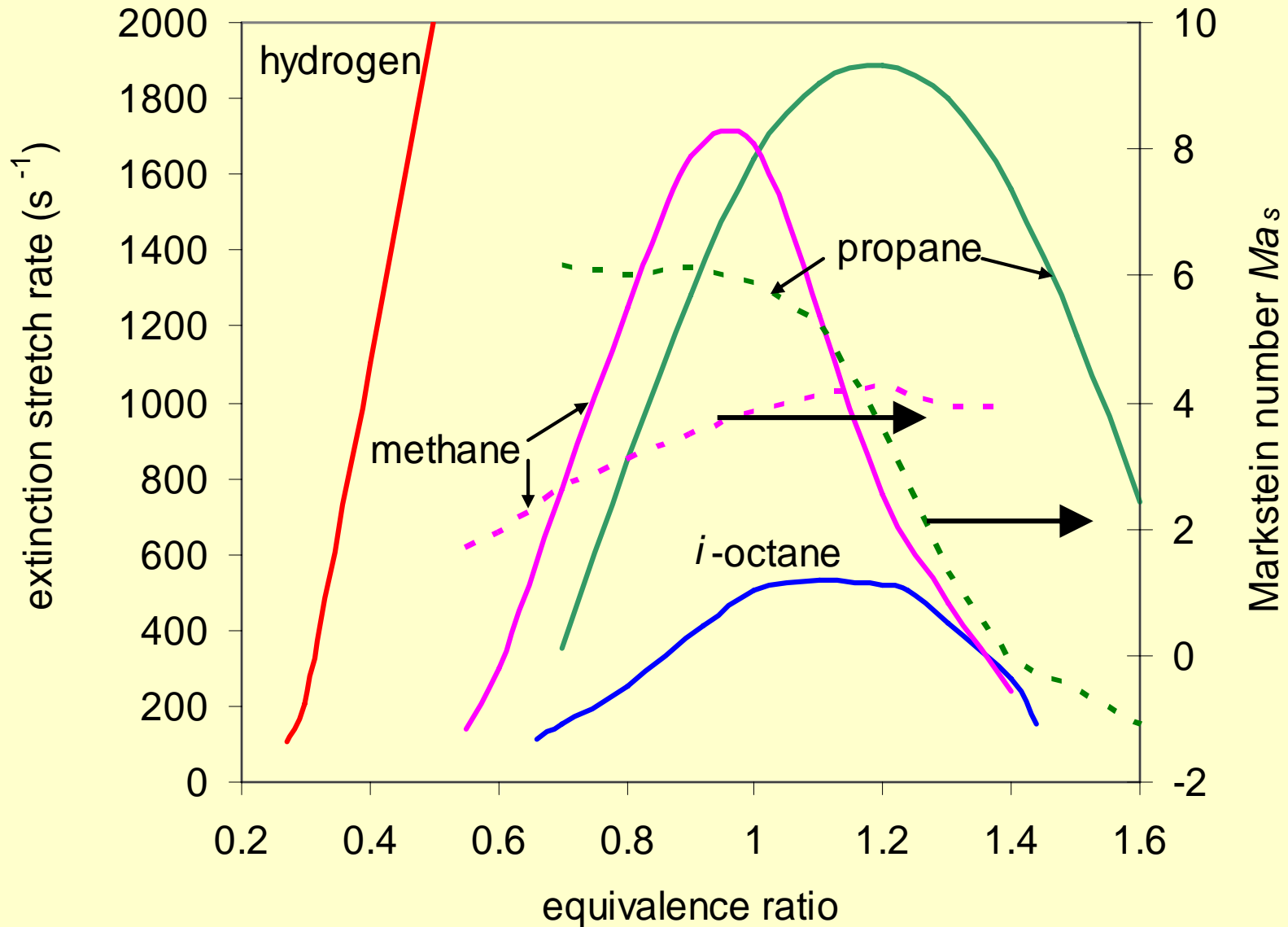


# Burners and Burning Velocities

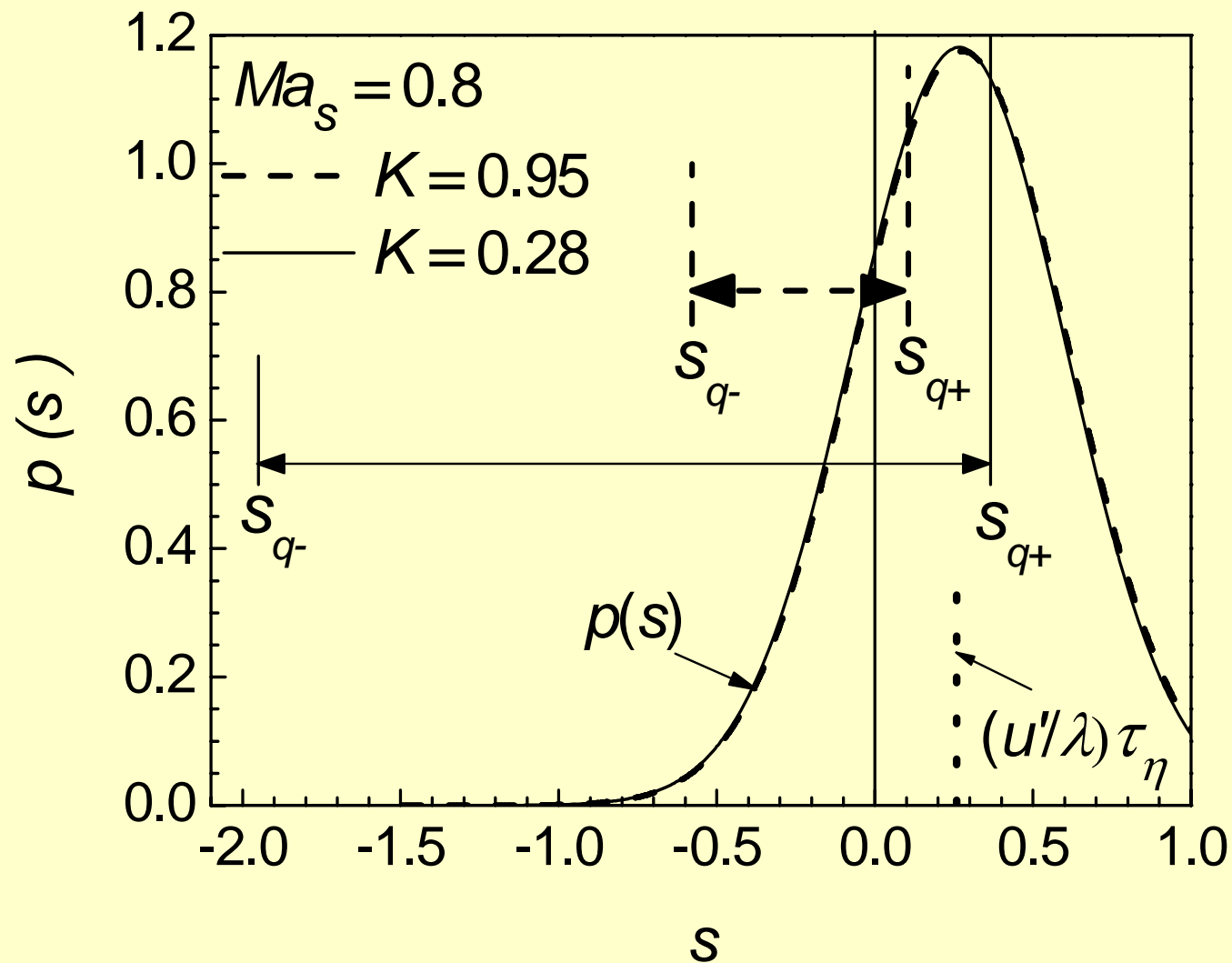
- 
- Counter-flow, opposed jet flame



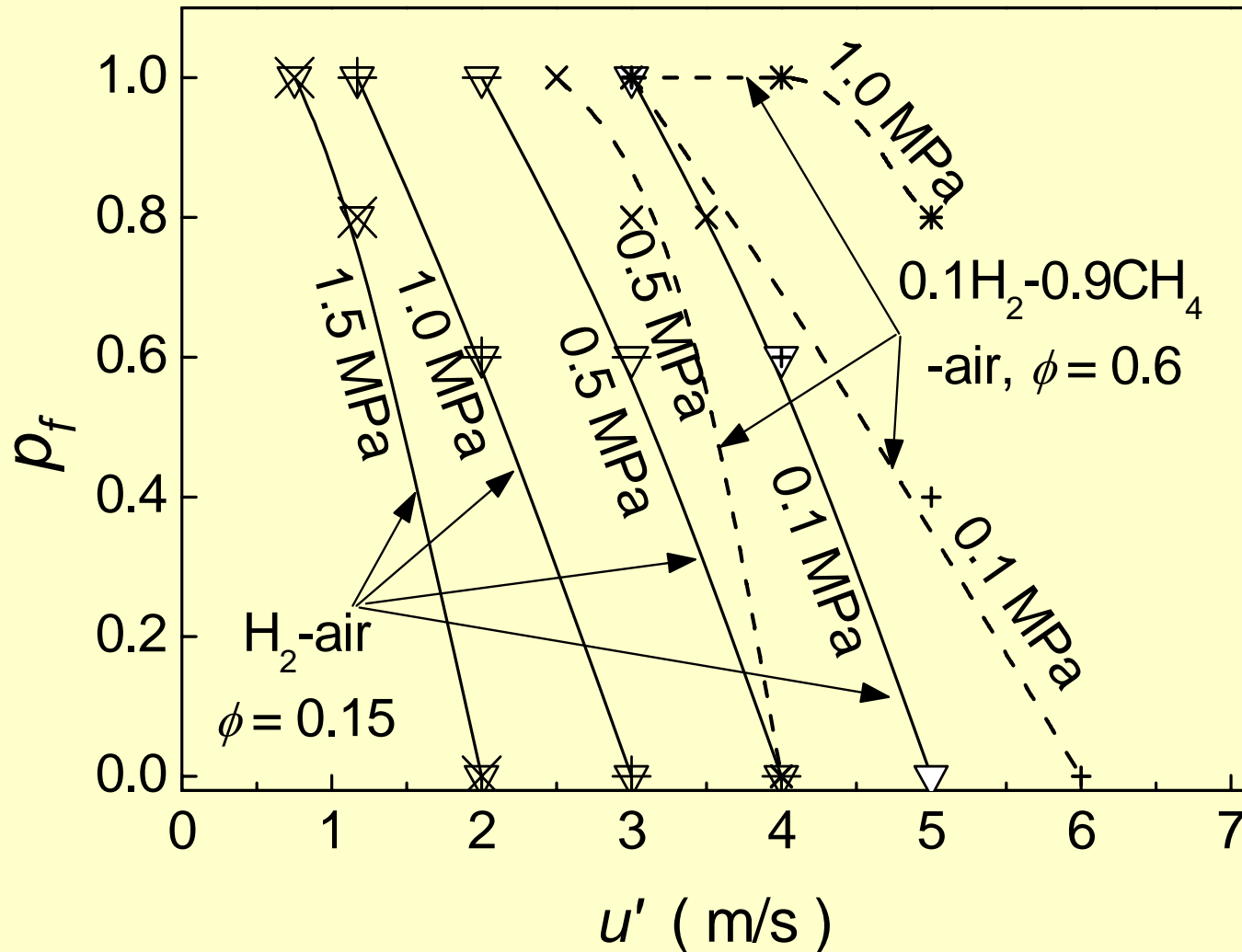
# Flame Extinction Stretch Rates



# Distribution of Flame Stretch Rates



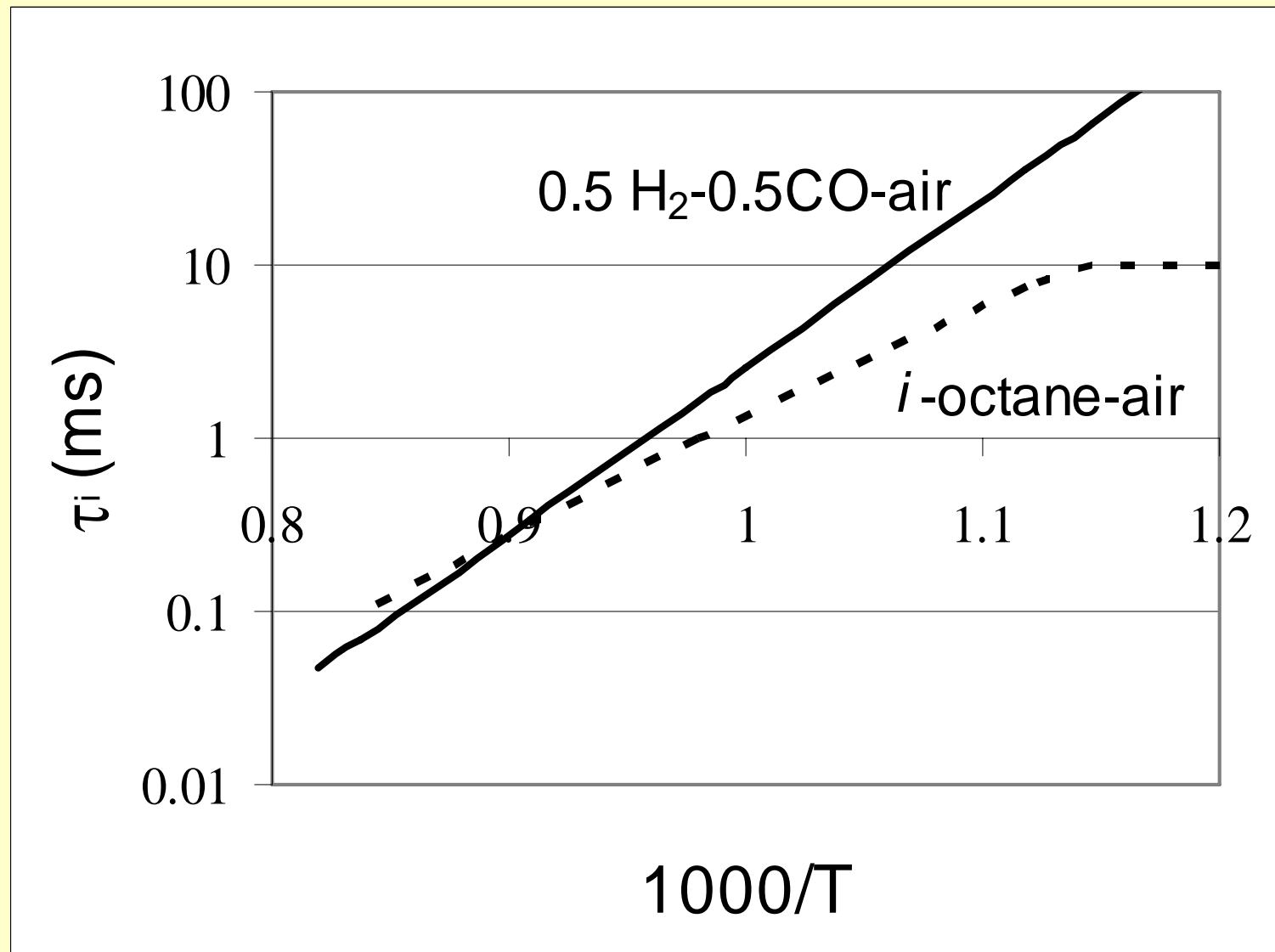
# Experimental Probabilities of Flame Propagation



# Probabilities of Flame Quenching in Bomb and Engines

Mixture	$\phi$ bomb	$\phi$ engine	$Ma_s$	$u_\ell$ (m/s)	NO <sub>x</sub> ppm	Ind. thermal eff. (%)
<i>i</i> -octane-air	0.78	0.71	0.8	0.150	LNT	unknown
CH <sub>4</sub> -air	0.57	0.62	-2.2	0.017	20	41.1
H <sub>2</sub> -air	0.17	0.20	-2.5	0.030	0	33.2

# Variations in Ignition Delay Time at 4 MPa

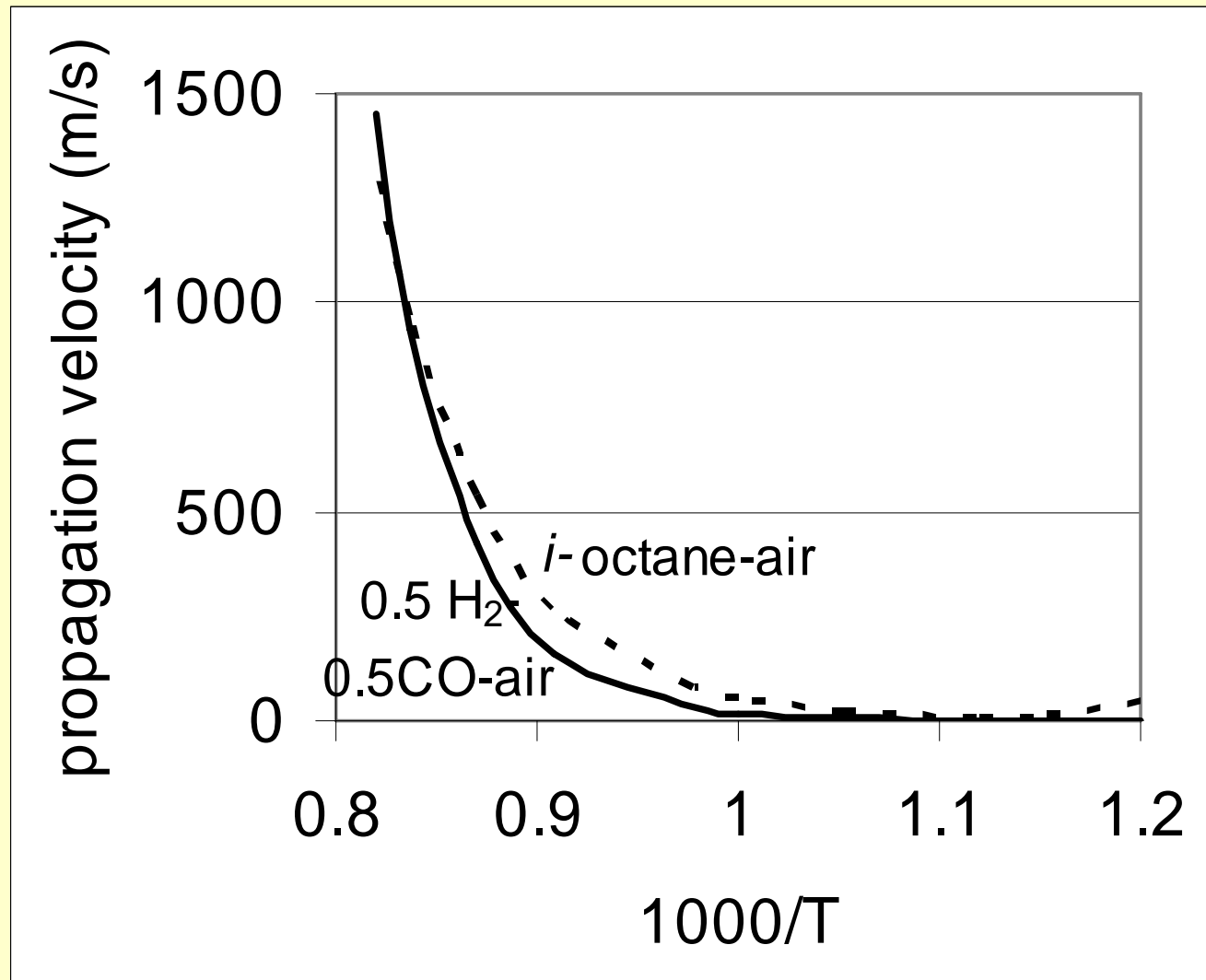


# Propagation Velocity from Hot Spot

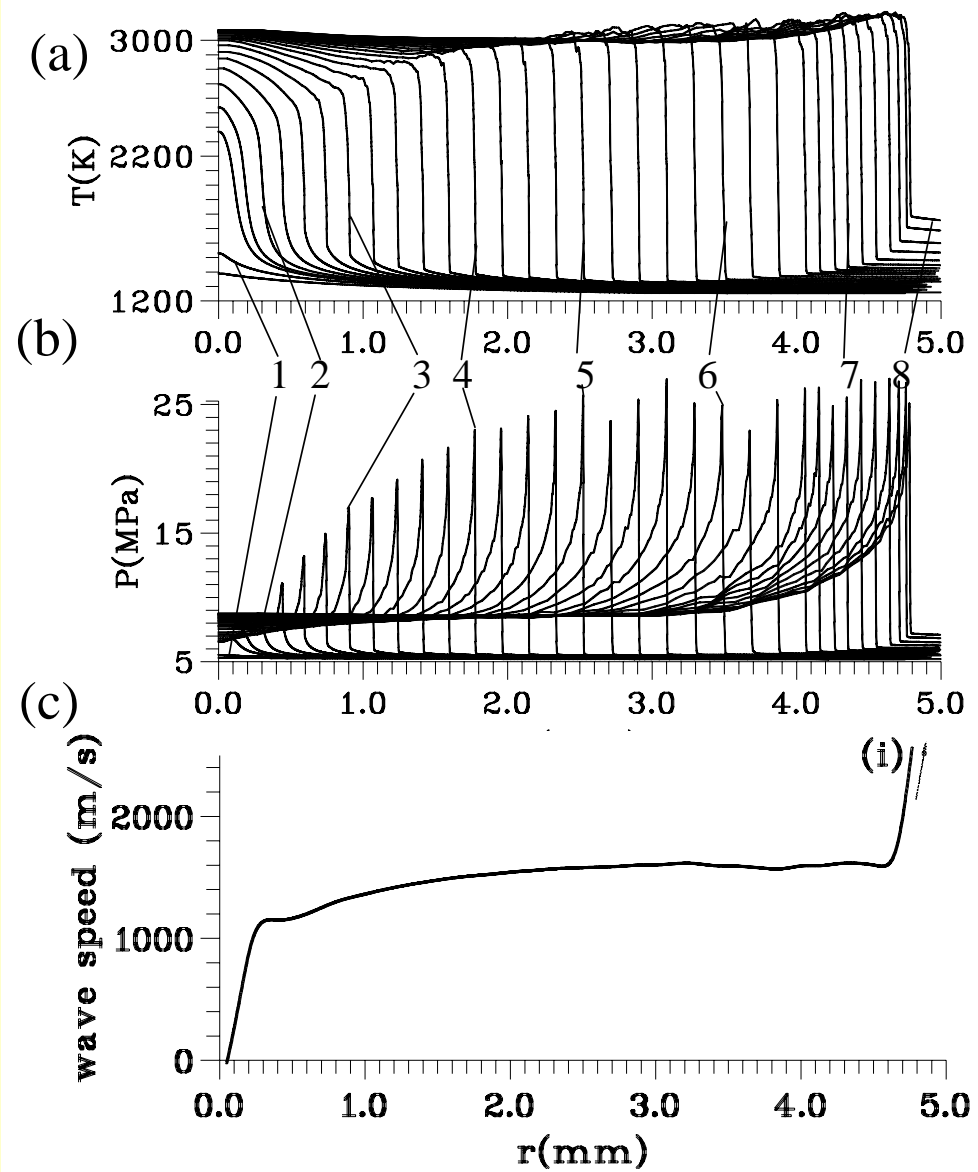
$$u_a = \left( \frac{\partial r}{\partial T} \right) \left( \frac{\partial T}{\partial \tau_i} \right)$$

$$\left( \frac{\partial T}{\partial r} \right)_c = \frac{1}{a(\partial \tau_i / \partial T)}$$

# Propagation Velocity from Hot Spot



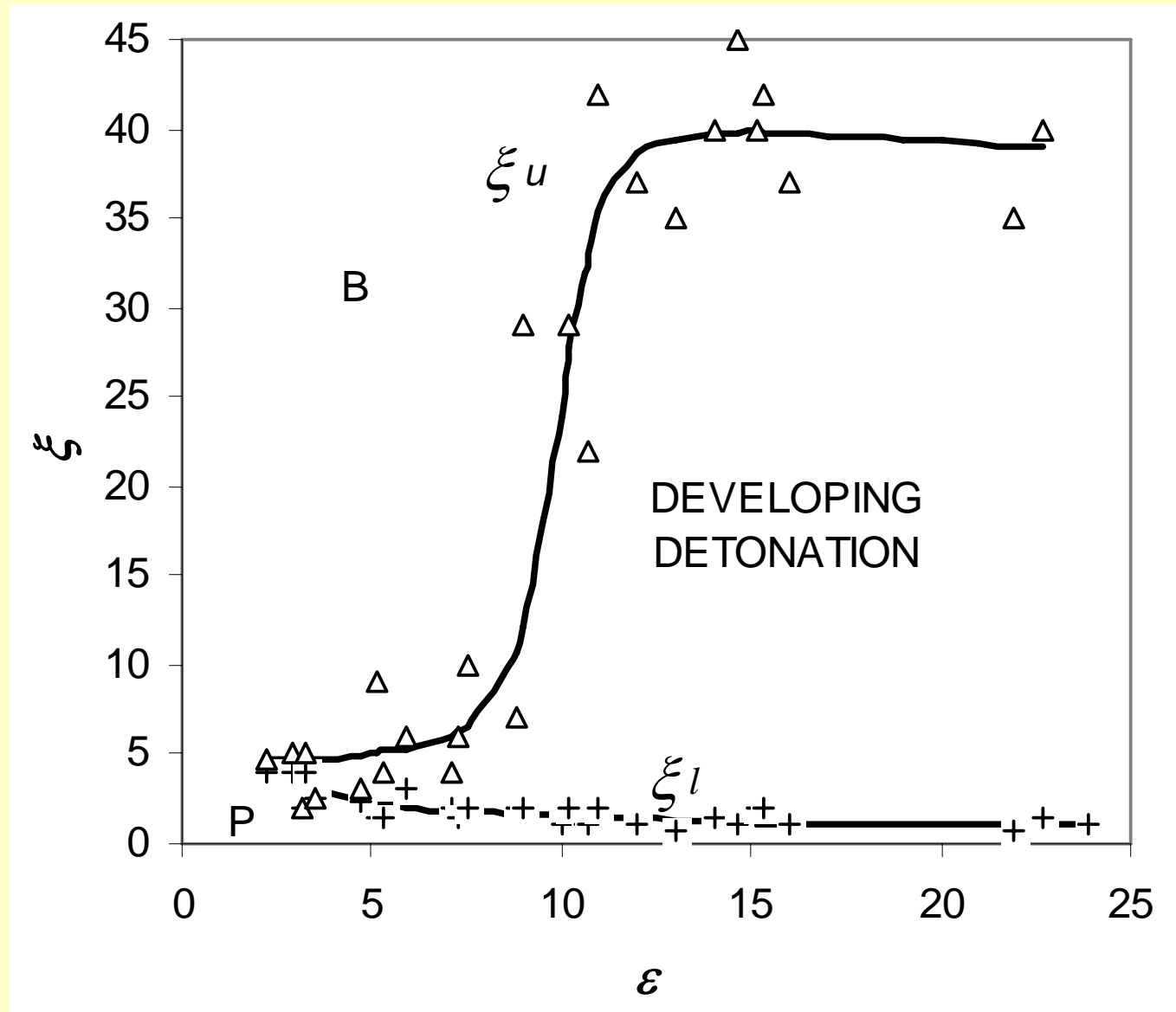
# Developing Detonation



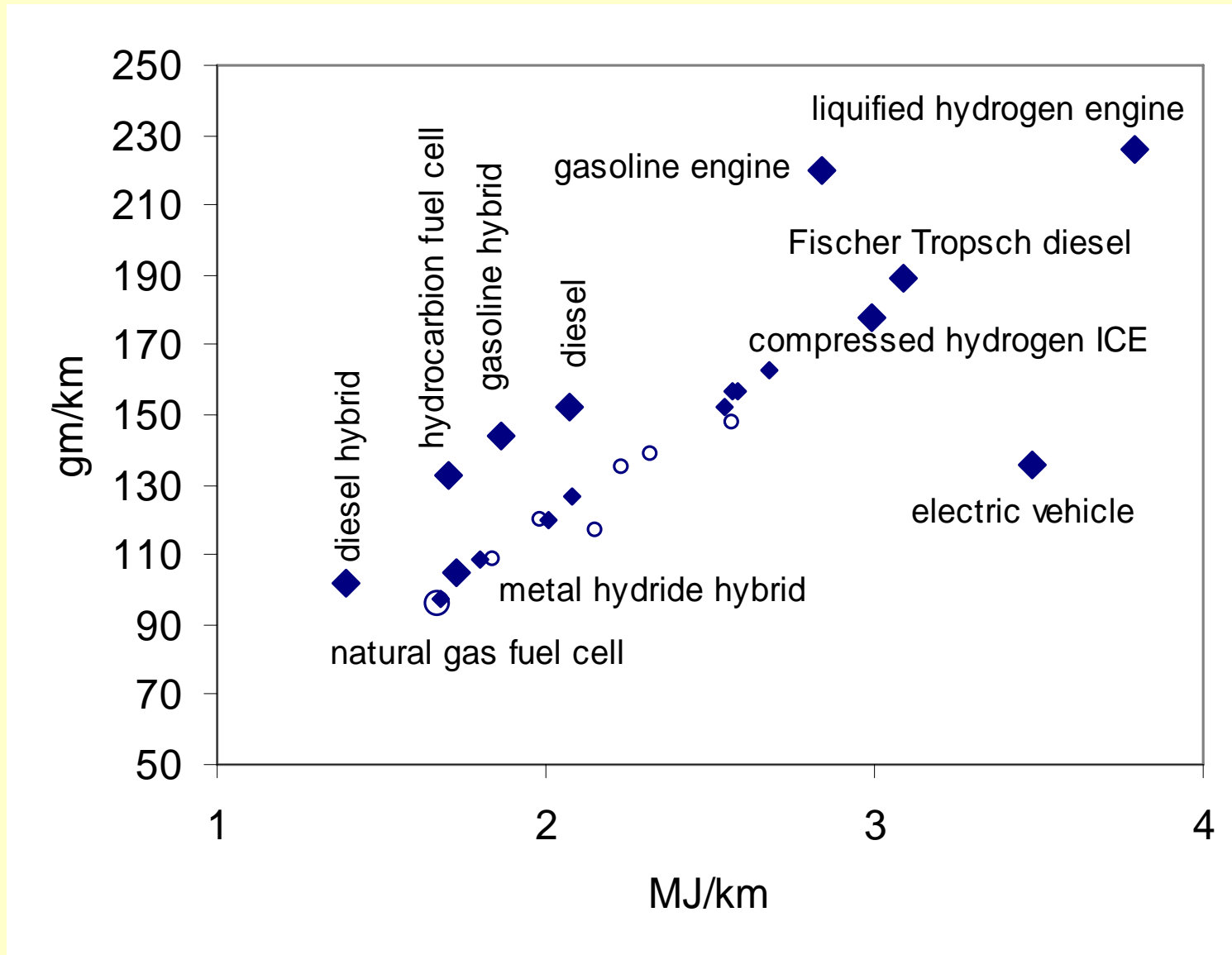
# Developing Detonation

$$\xi = \left( \frac{\partial T}{\partial r} \right) \left( \frac{\partial T}{\partial r} \right)_c^{-1}$$

$$\varepsilon = (r_o/a)/\tau_e$$



# Well to Wheel Energy and CO<sub>2</sub> Emissions



# Well to Wheel: CNG and H<sub>2</sub> Compared

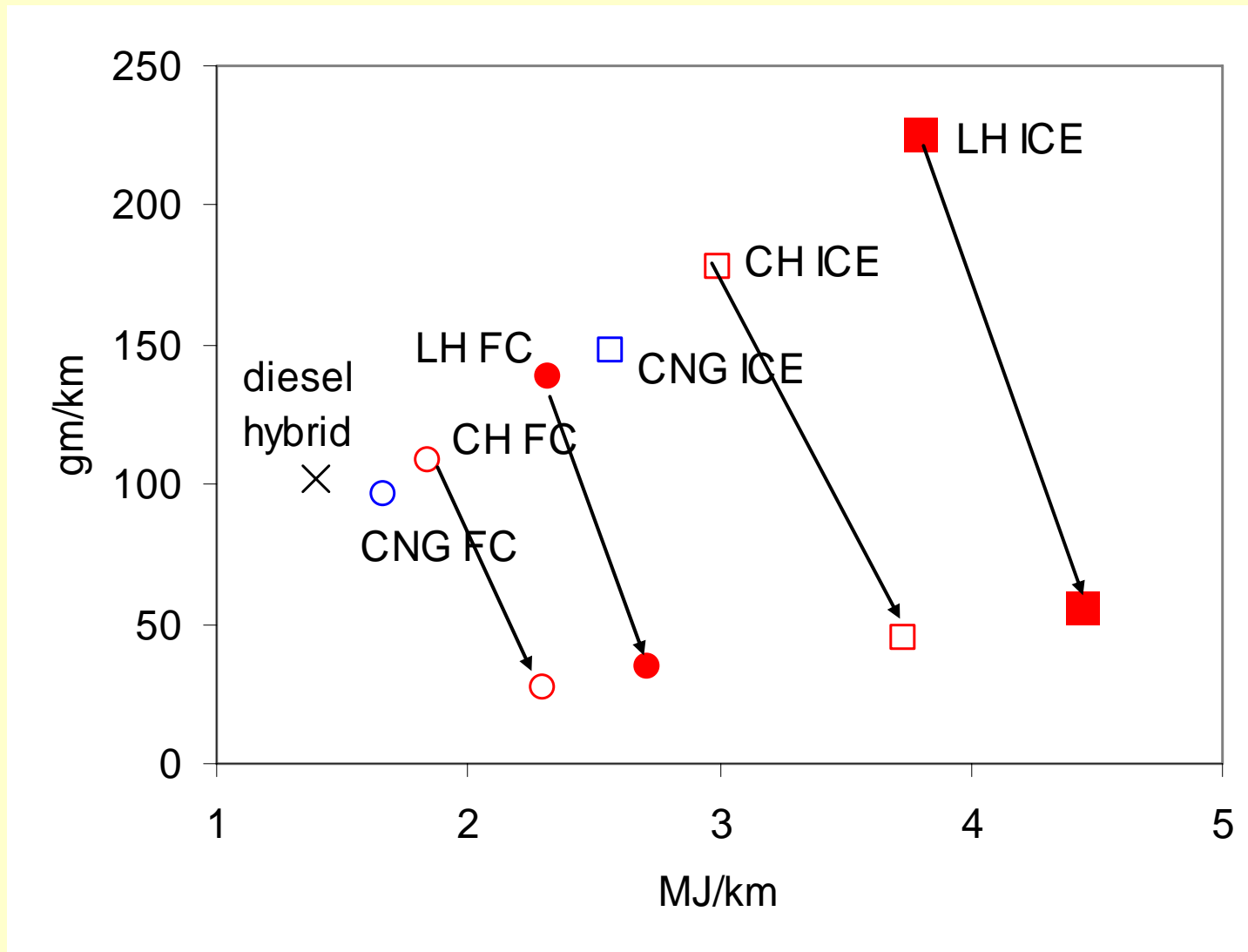
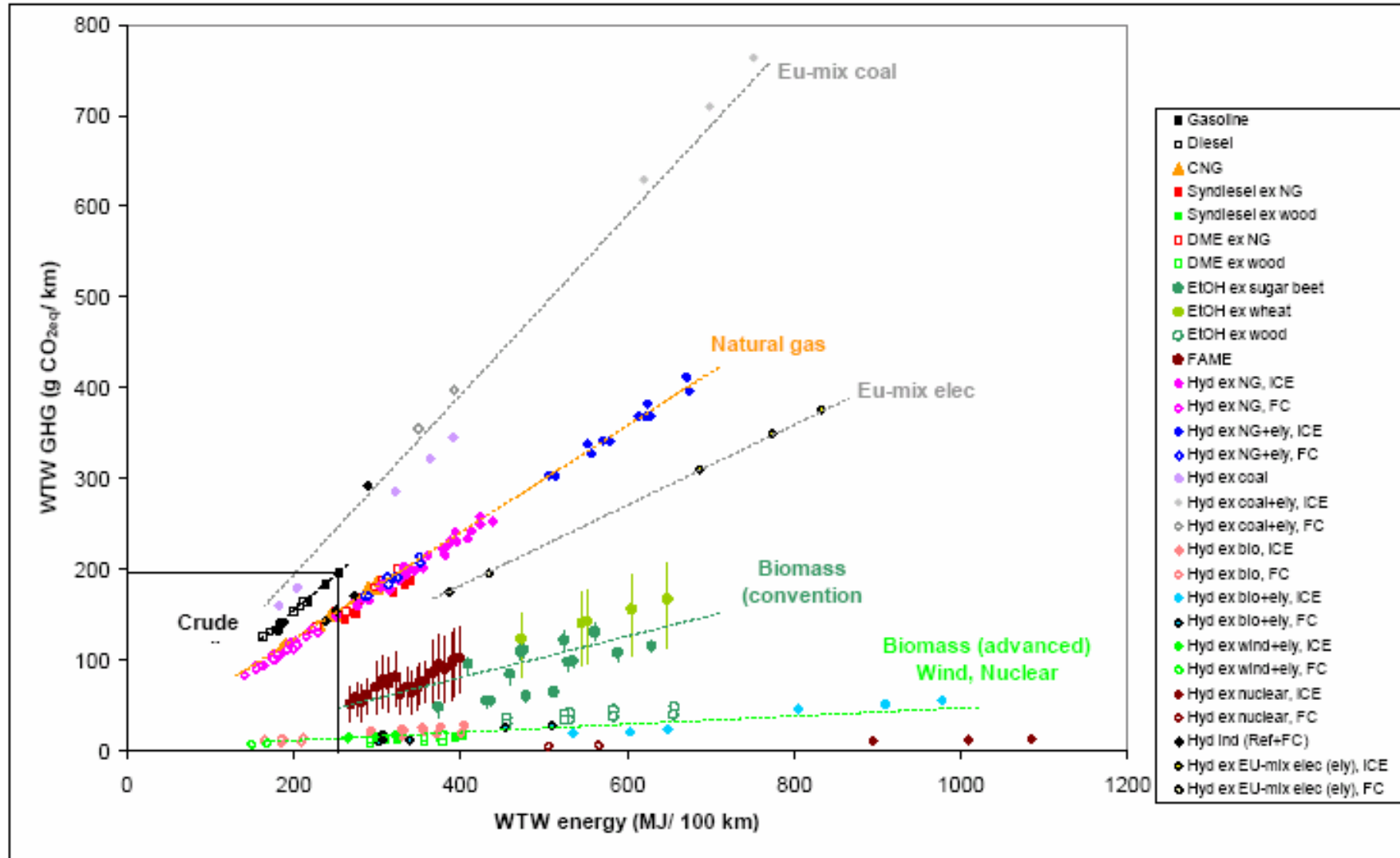


Figure 4.1-1

WTW energy and GHG emissions for all pathways and powertrain combinations



Abbreviations: "Ely": electrolysis; "ind": indirect