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Effect of Hydrogen Enrichment on Combustion and Emissions of a Diesel HCCI Engine

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Background

- HCCI combustion offers higher fuel efficiency and lower pollutant emissions
- However, HCCI combustion has some drawbacks
  - Higher CO and HC emissions
  - Phasing control problem
- Hydrogen offers advantages for flames and SI engines
  - Higher flame speed and leaner flammability limits, intensifying high temperature kinetics process
  - Low cetane number, helping control HCCI combustion phasing
- Hydrogen enriched HCCI combustion studies
  - Effect of hydrogen enrichment on DME HCCI combustion (Shudo et al, 2002 – 2004), retarding combustion phasing
  - Effect of RG on NG and n-heptane HCCI combustion (Kongsereeparp et al., 2007, 2008; Hosseini et al., 2007, 2008), advancing NG combustion phasing and retarding n-heptane combustion phasing
- ***How does pure hydrogen enrichment affect diesel HCCI combustion?***

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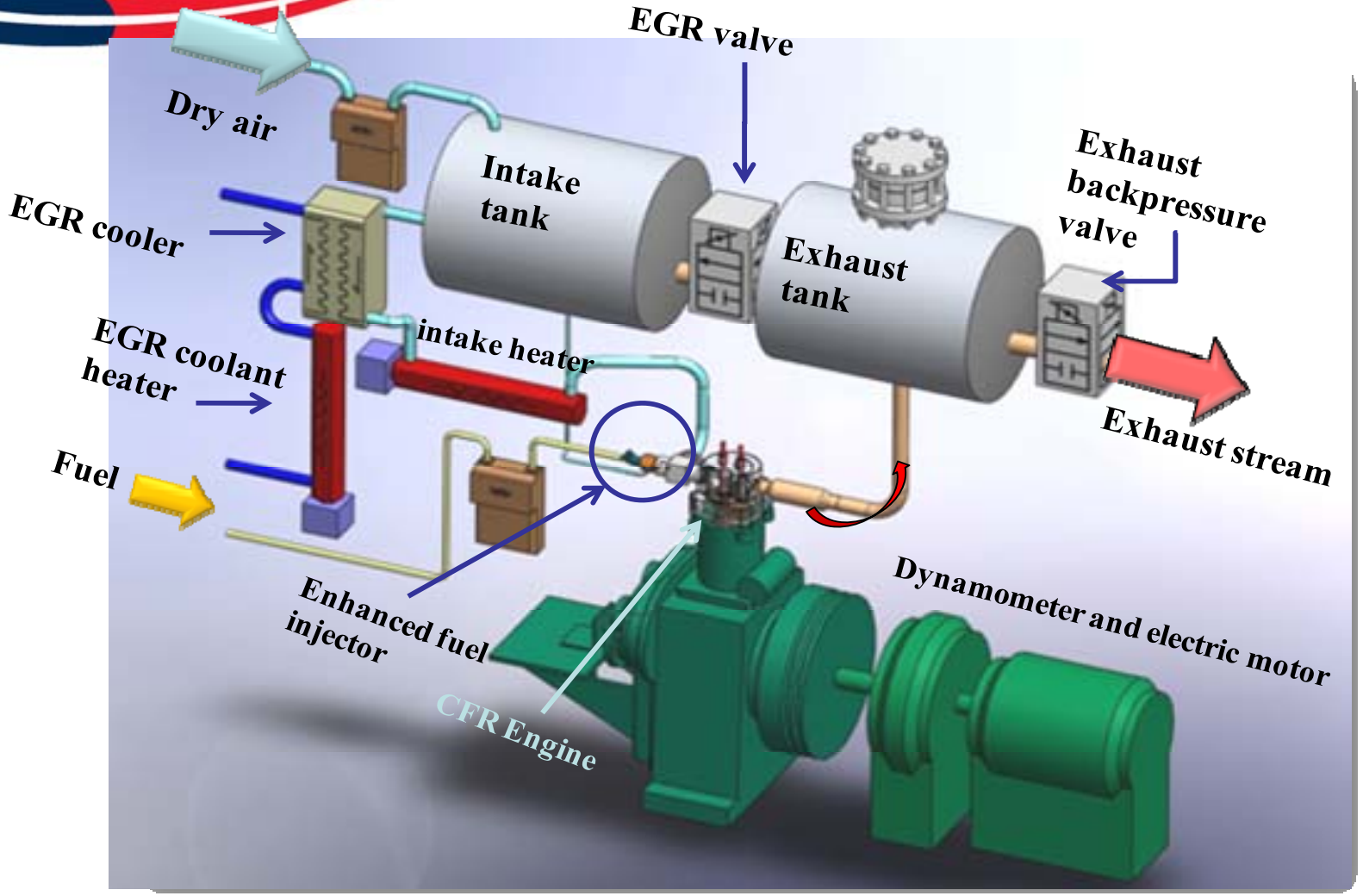
Objective

- Investigate the effect of hydrogen enrichment on combustion and emission characteristics of diesel HCCI combustion

- Fuel: **n-heptane**, a primary reference fuel for diesel

Experimental Facility



- A modified CFR engine

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Engine Specifications

Cylinder Bore	82.55 mm
Stroke	114.3
Displacement Volume	611.7 cc
Connection Road Length	254 mm
Compression Ratio	4.6 ~ 16
Combustion Hammer	Pancake shape
Intake valve open Intake valve close Exhaust valve open Exhaust valve close	10 CA ATDC 34 CA ABDC 40 CA BBDC 5 CA ATDC
Fuel System	Air-assisted port fuel injection

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Experimental Conditions

- Engine speed: 900 rpm
- Manifold absolute pressure: 150 kPa
- Exhaust pressure: 170 kPa
- Intake mixture temperature: 75 ^{o}C
- EGR level: 60%, 0%
- Relative air/fuel ratio: 1.2, 3.5
- Hydrogen fraction: 0 ~ 15%
- Compression ratio: varied from a low value that caused COV_{IMEP} of about 5%, to a value that caused P rise rate of about 10 bar/^{o}CA

$$H2 = m_{H2}/(m_{H2}+m_{n\text{-}heptane})$$

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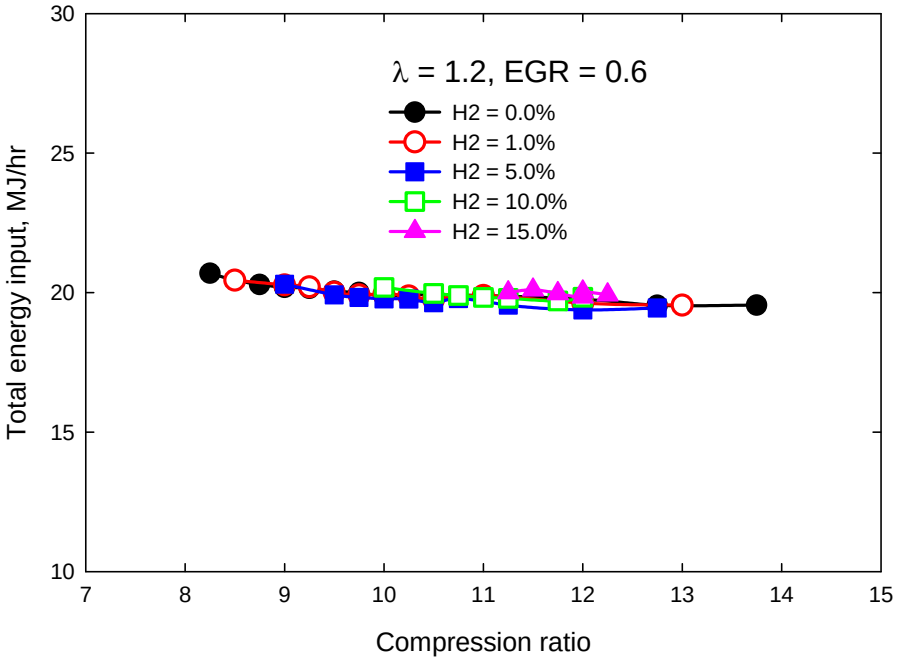
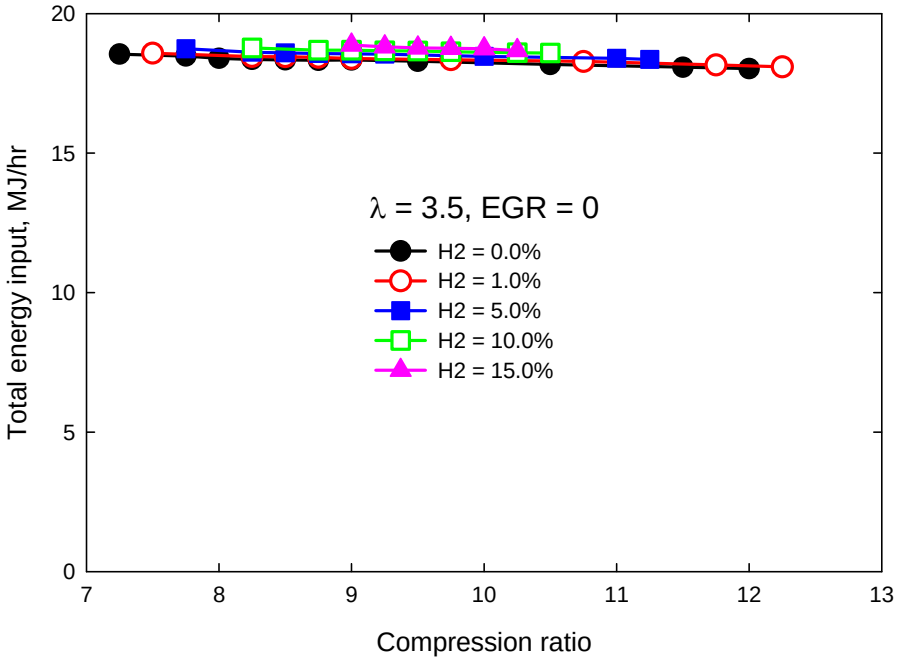
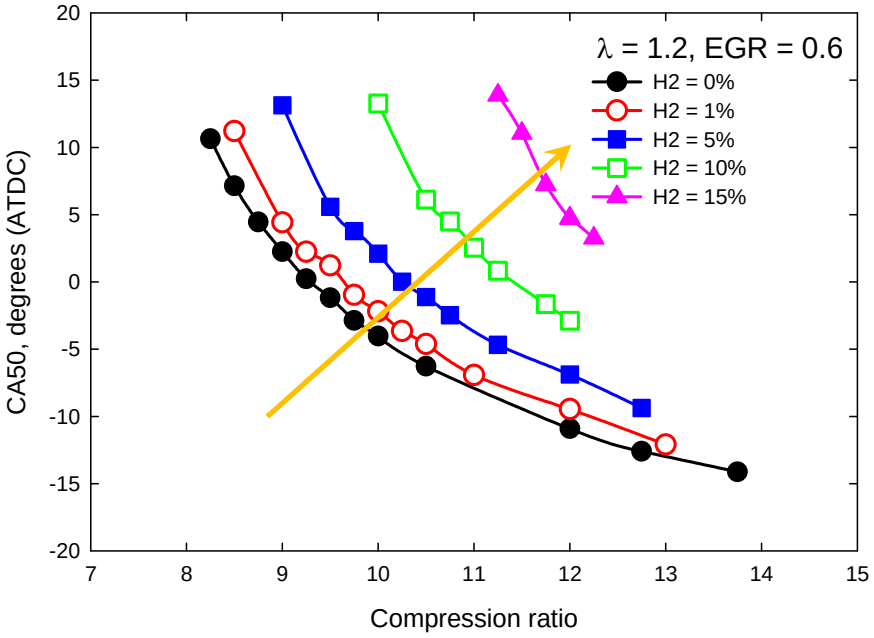
Total Energy Input

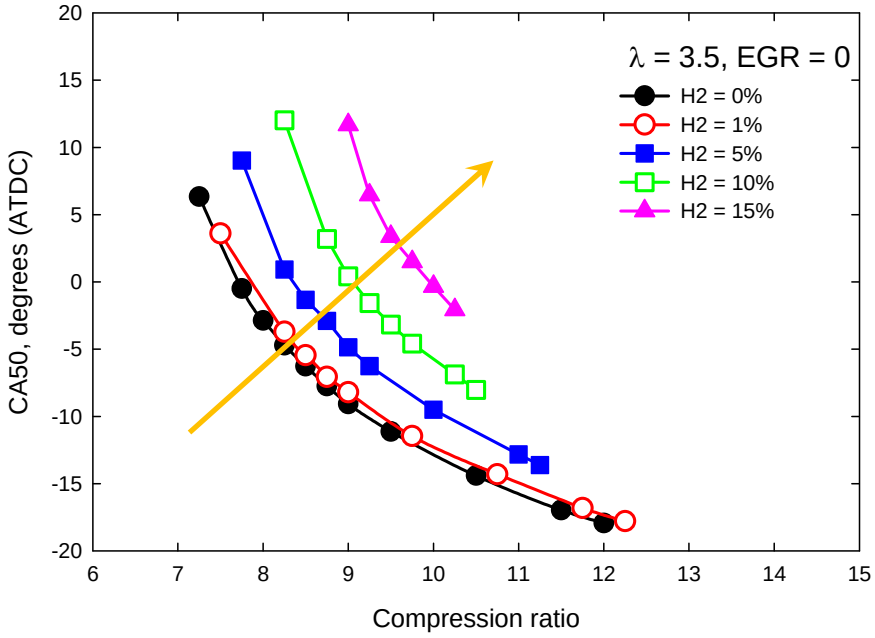




- Variation in energy input is less than 6% for all experiments

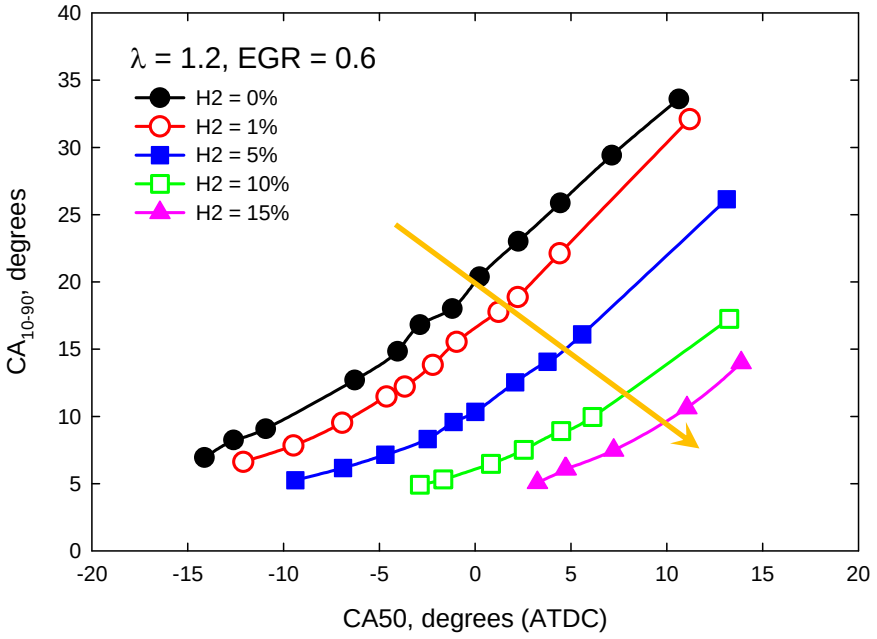
Combustion Phasing

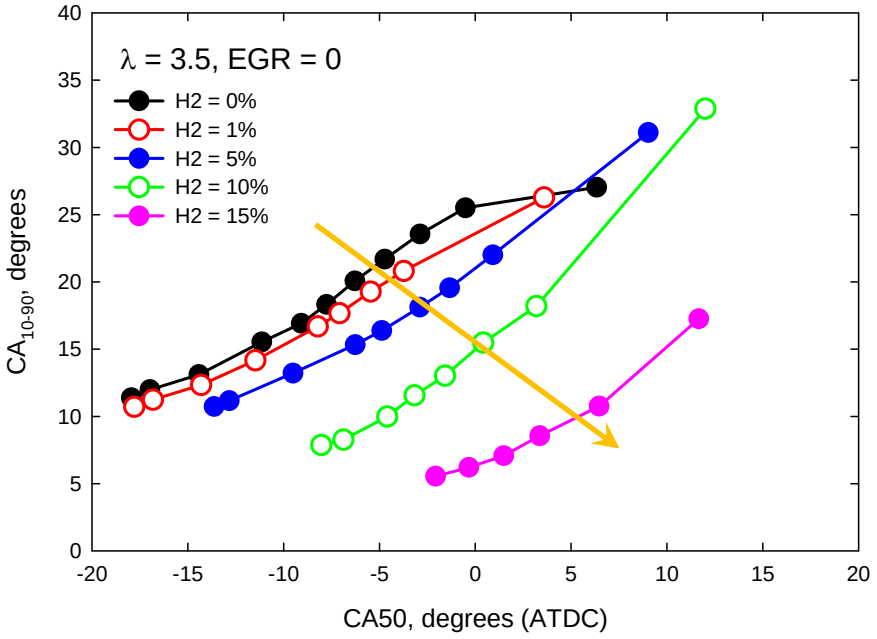




- H_2 enrichment retards combustion phasing, possibly due to the competition for OH between H_2 and H abstraction process at low heat release stage

Combustion Duration





- Combustion duration decreases with increasing the fraction of H_2, possibly due to the intensified high temperature kinetics process $H + O_2 = O + OH$

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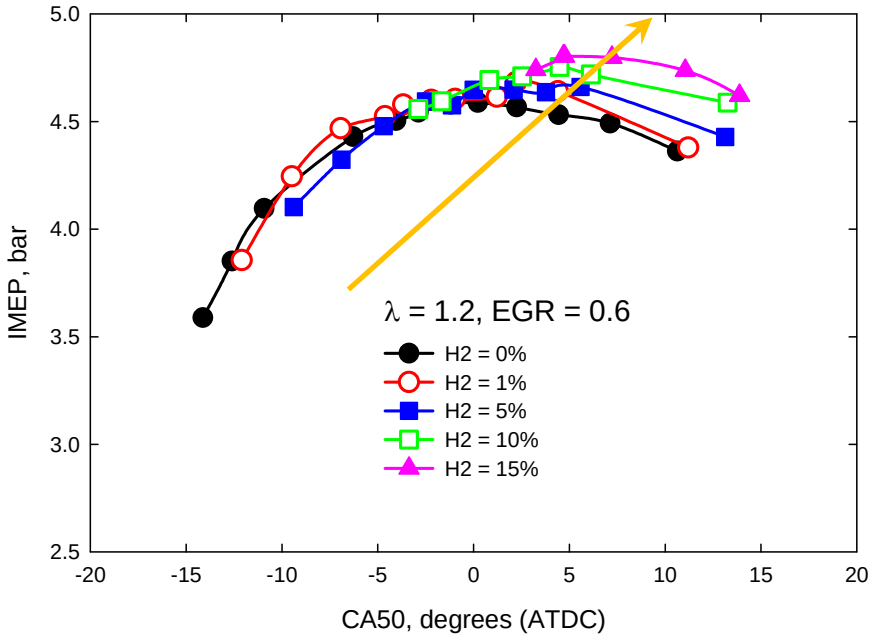
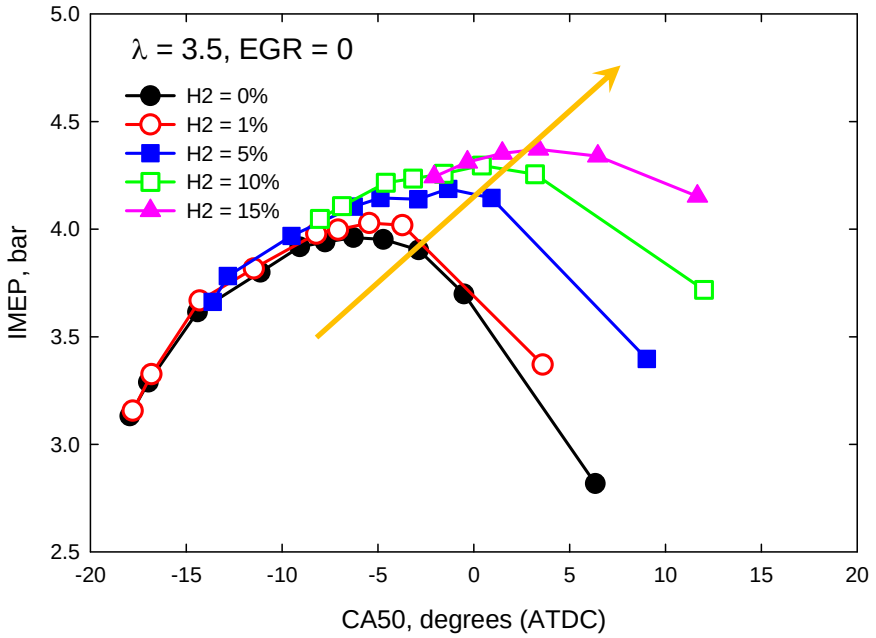
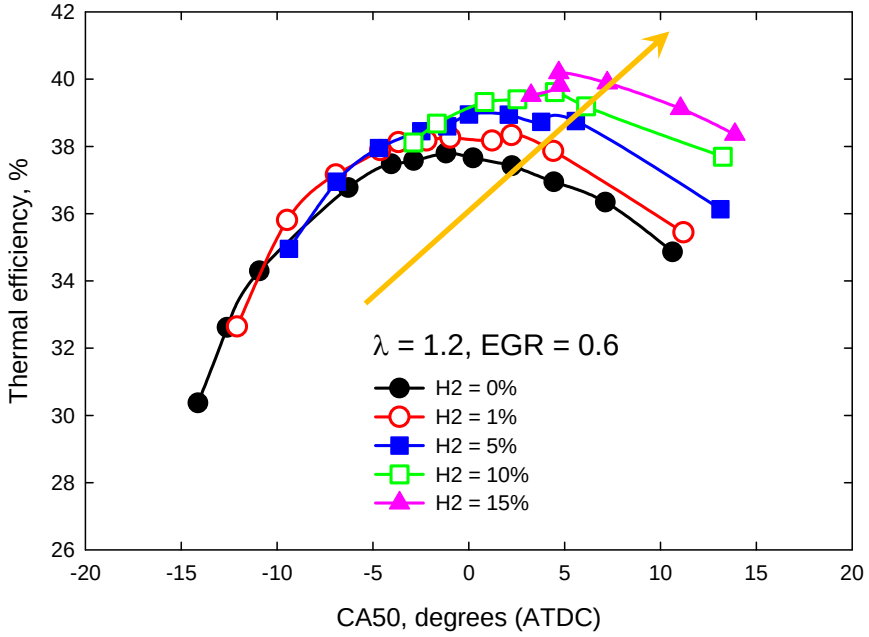
Indicated Mean Effective Pressure

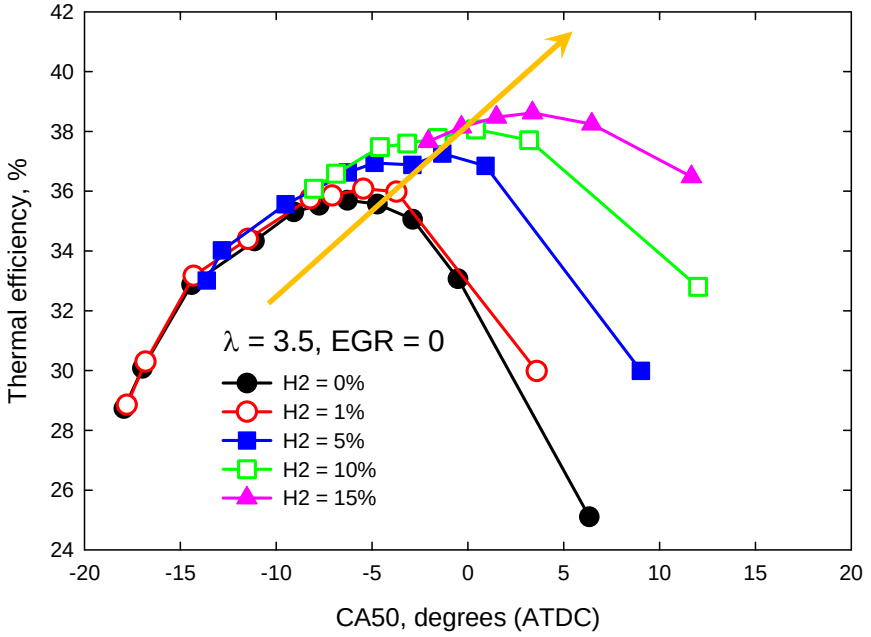




- H_2 enrichment increases IMEP

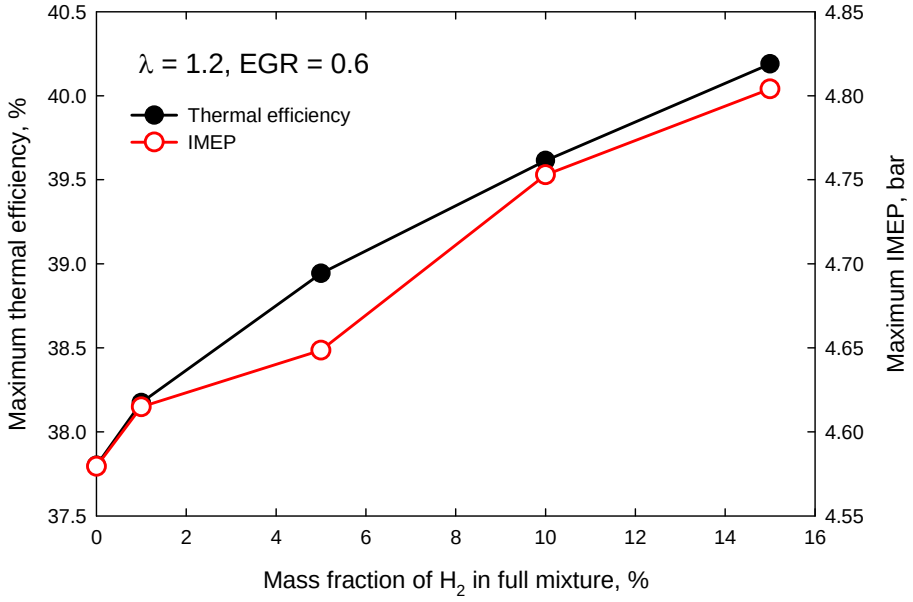
Thermal Efficiency

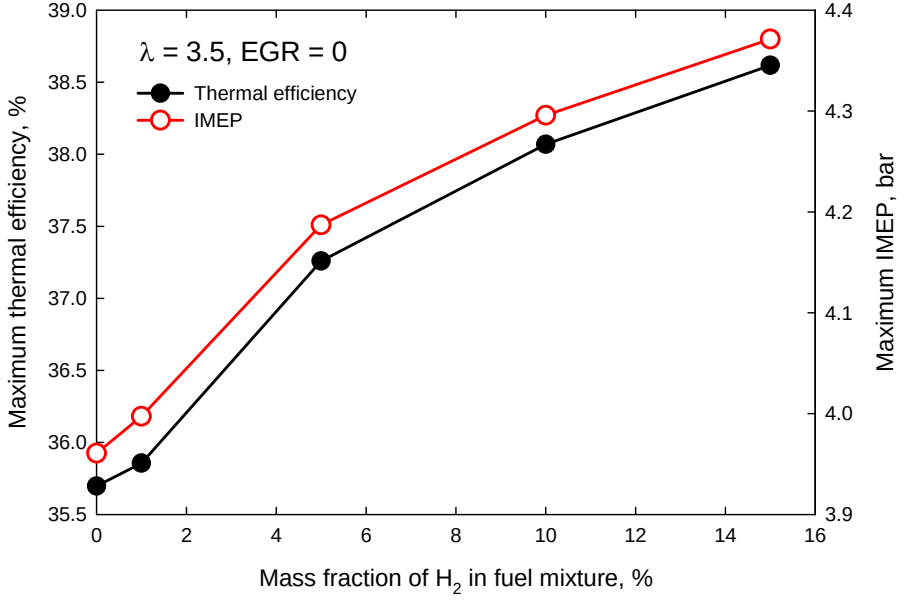




- Hydrogen enrichment improves thermal efficiency

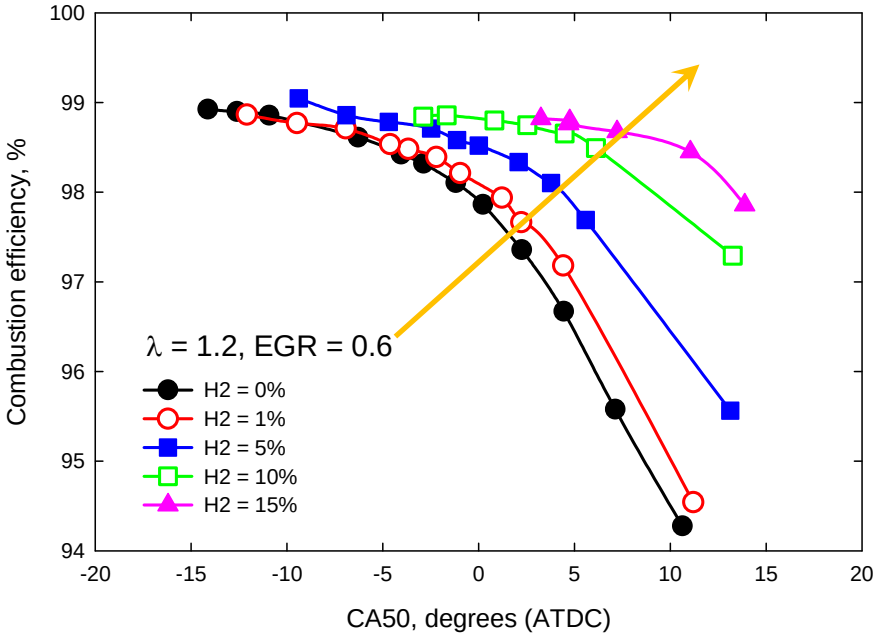
IMEP and Thermal Efficiency

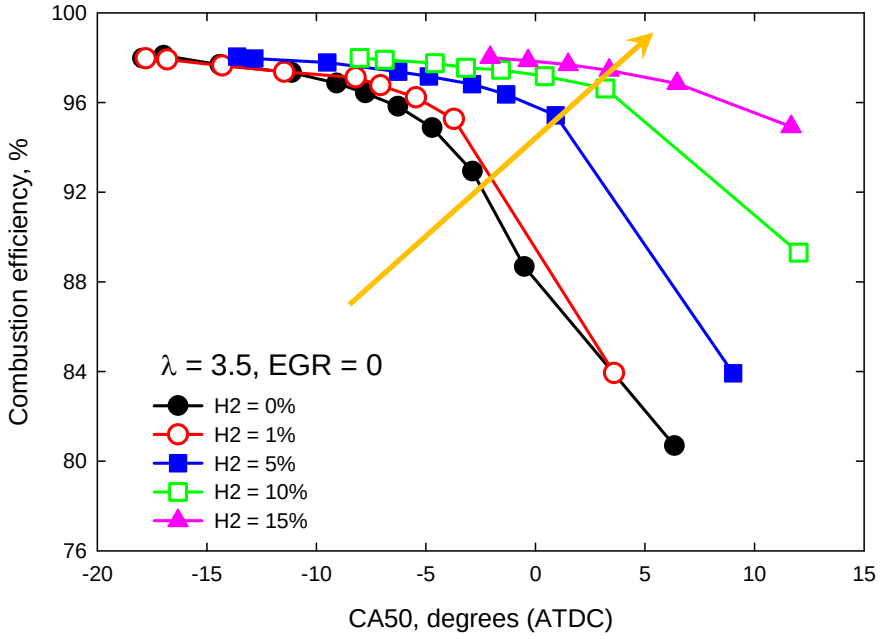




- Hydrogen enrichment increases IMEP and thermal efficiency, due to
  - optimized combustion phasing and increased compression ratio
  - Improved combustion efficiency
    - Shorter combustion duration
    - Lower CO emissions

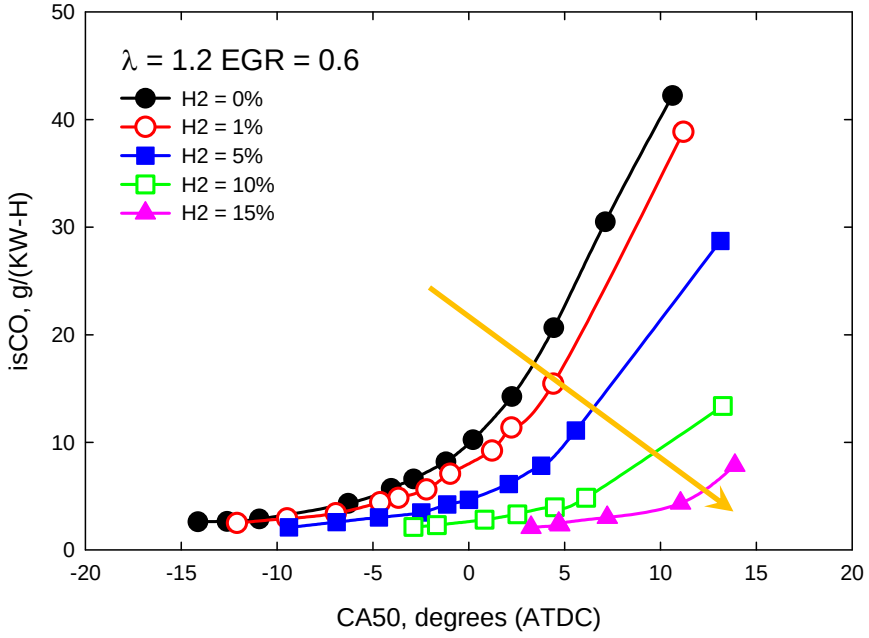
Combustion Efficiency

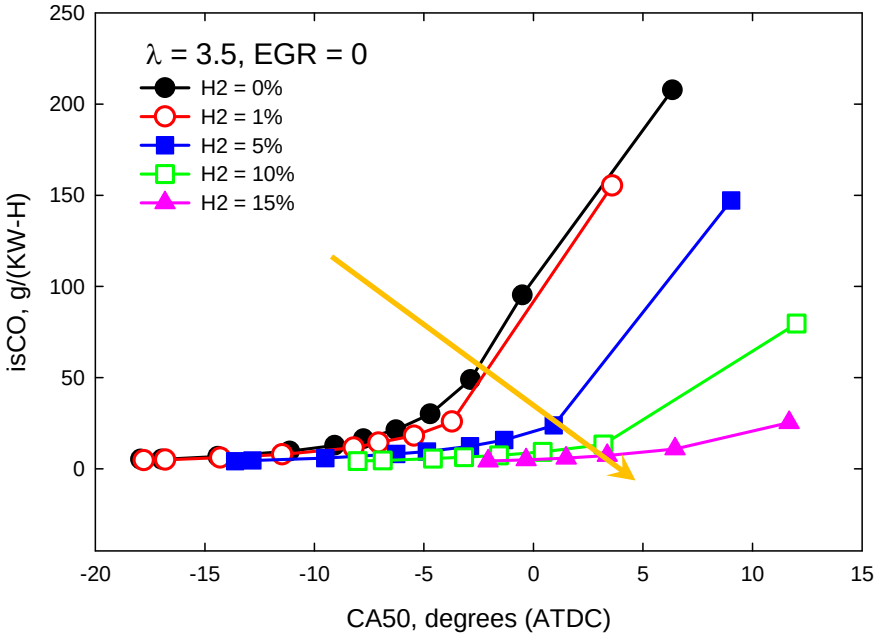




- Hydrogen enrichment seems to improve combustion efficiency

CO Emissions





- *CO emissions decrease due to hydrogen enrichment?*

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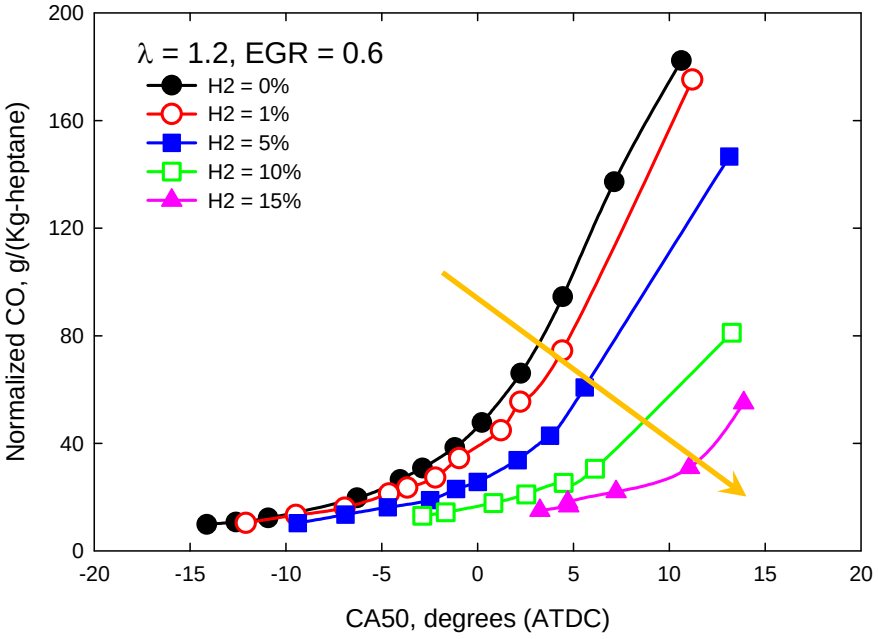
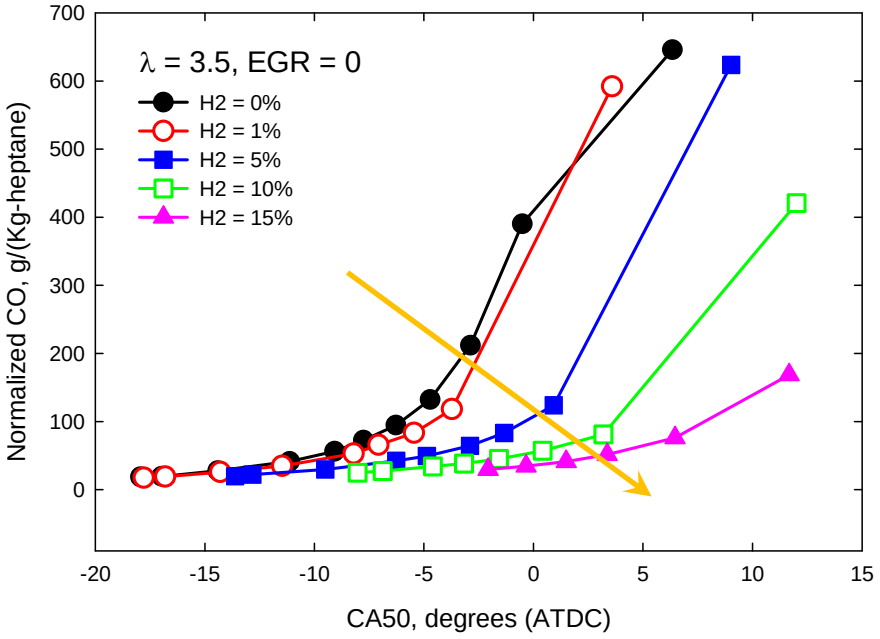
CO Emissions





- CO emissions decrease due to hydrogen enrichment

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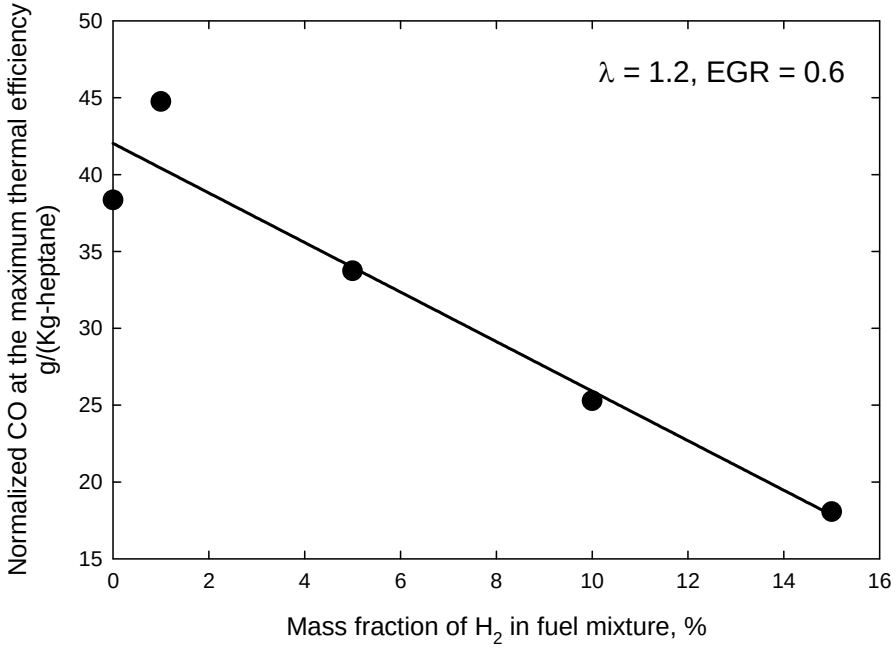
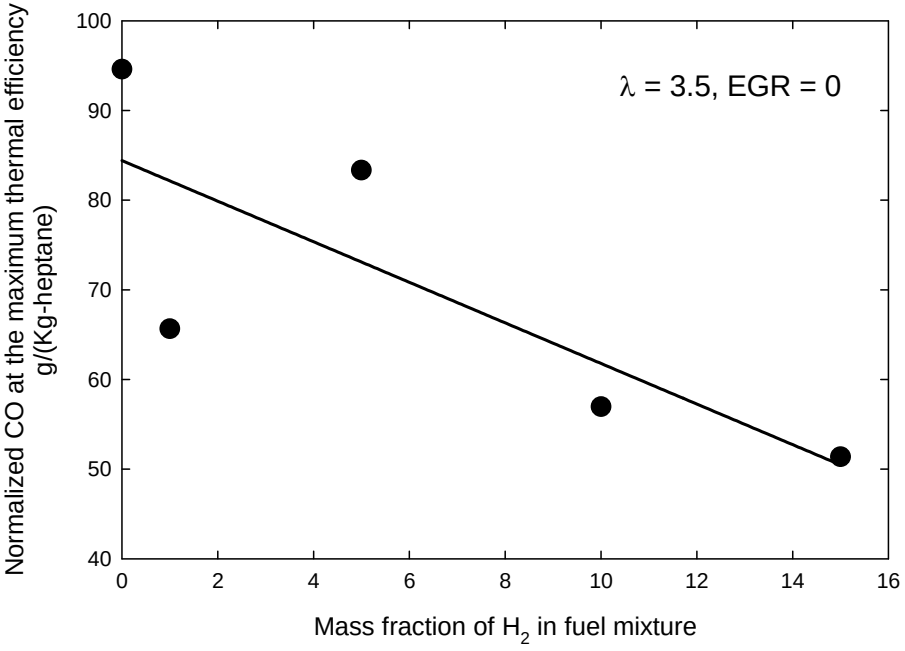
CO Emissions





- CO emissions do decrease due to hydrogen enrichment

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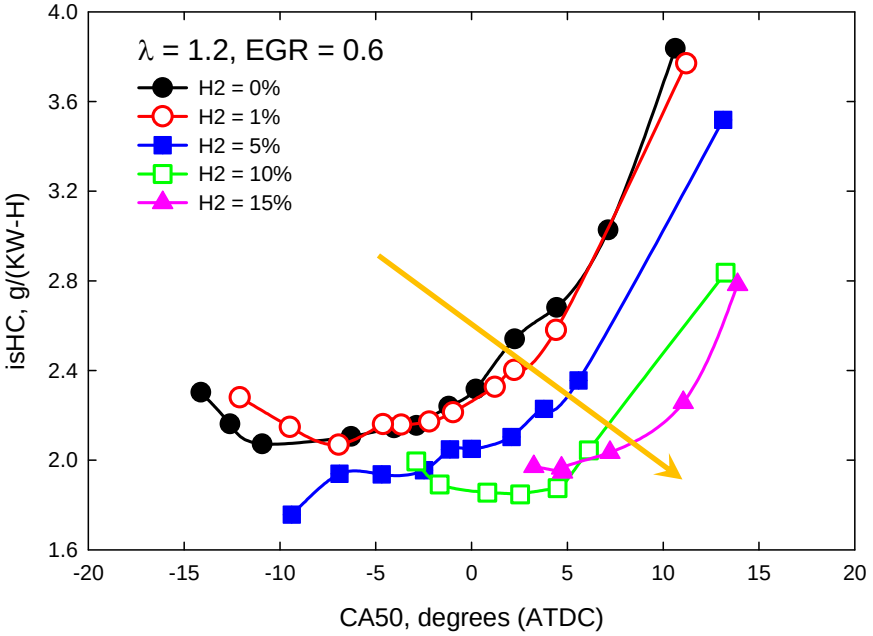
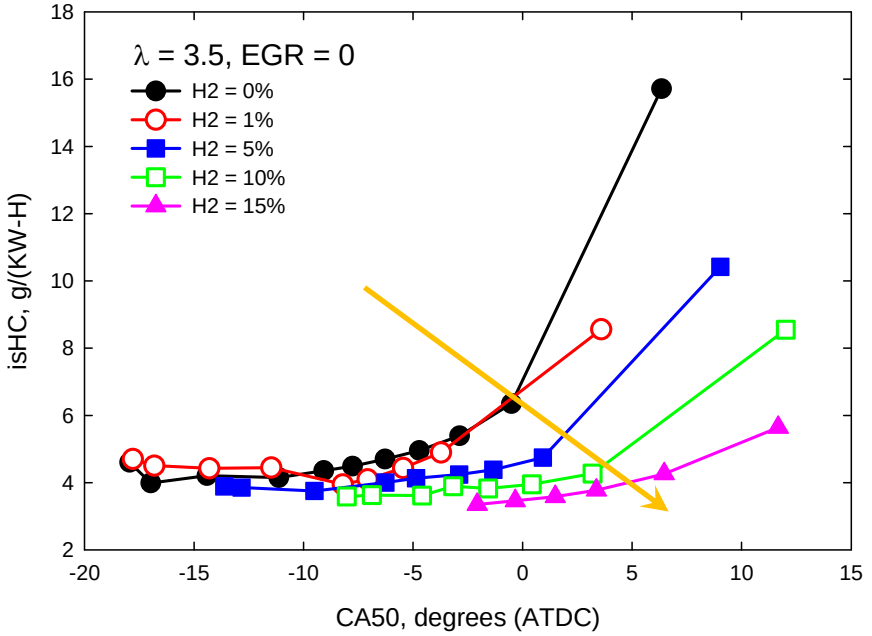
Unburned Hydrocarbon (HC) Emissions





- *HC emissions decrease?*

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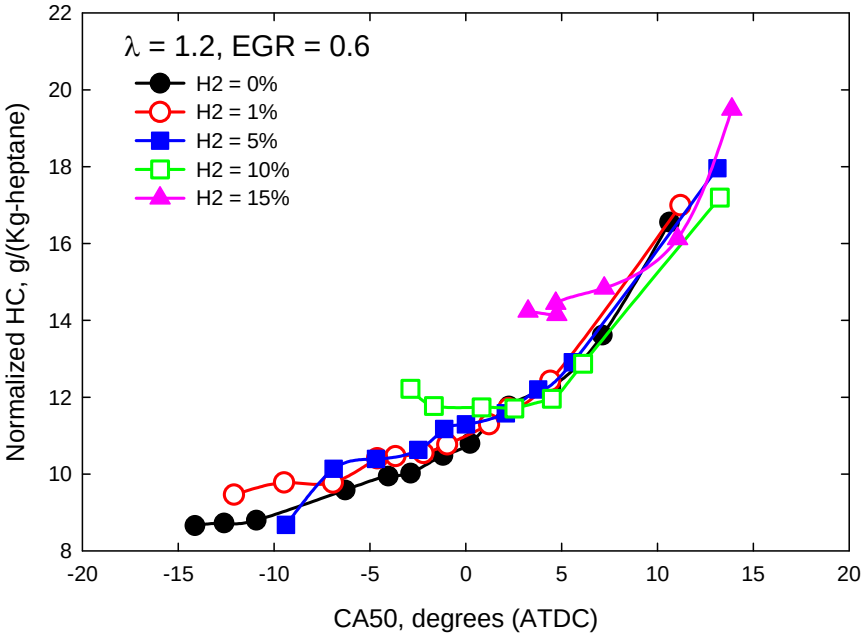
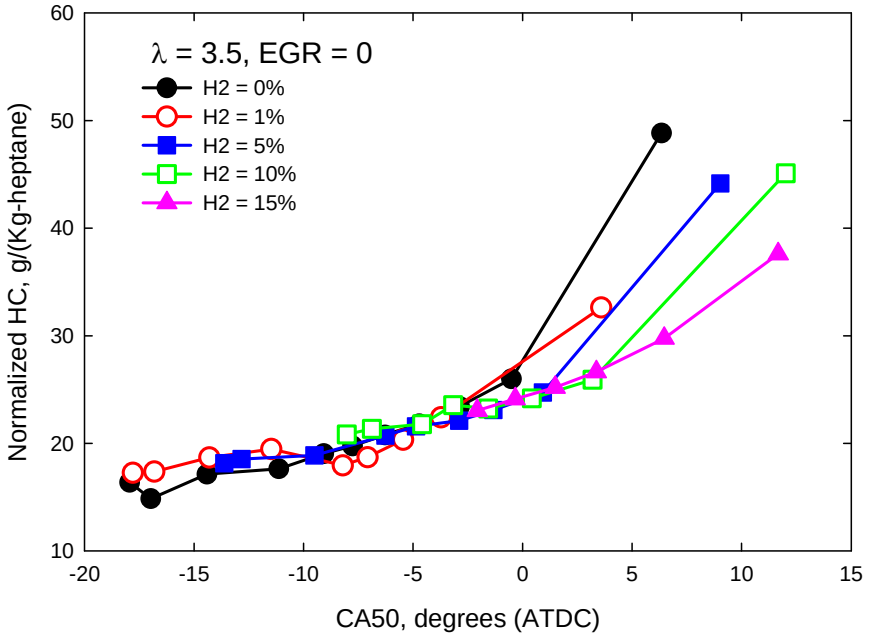
HC Emissions





- Hydrogen enrichment does not significantly affect HC emissions?

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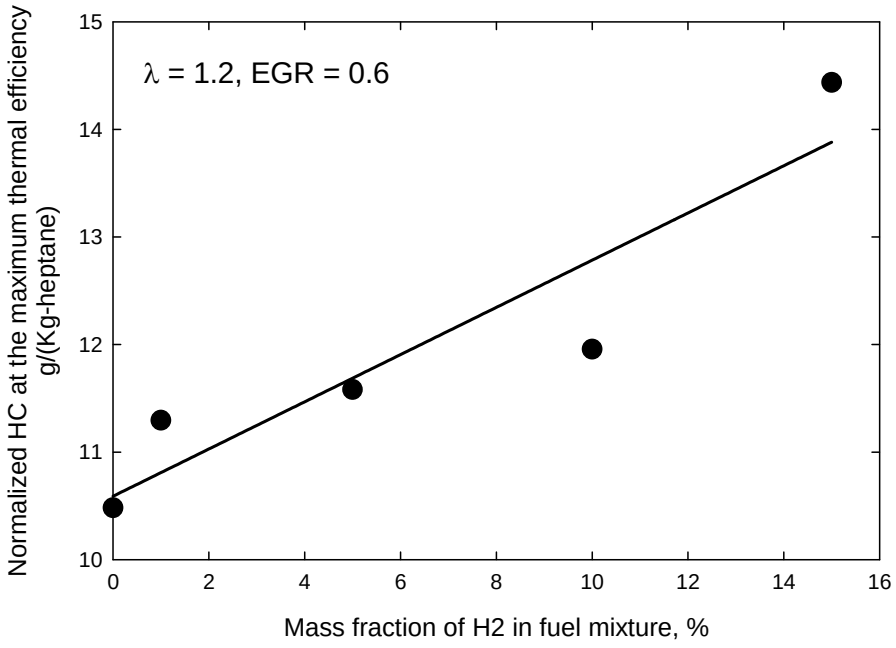
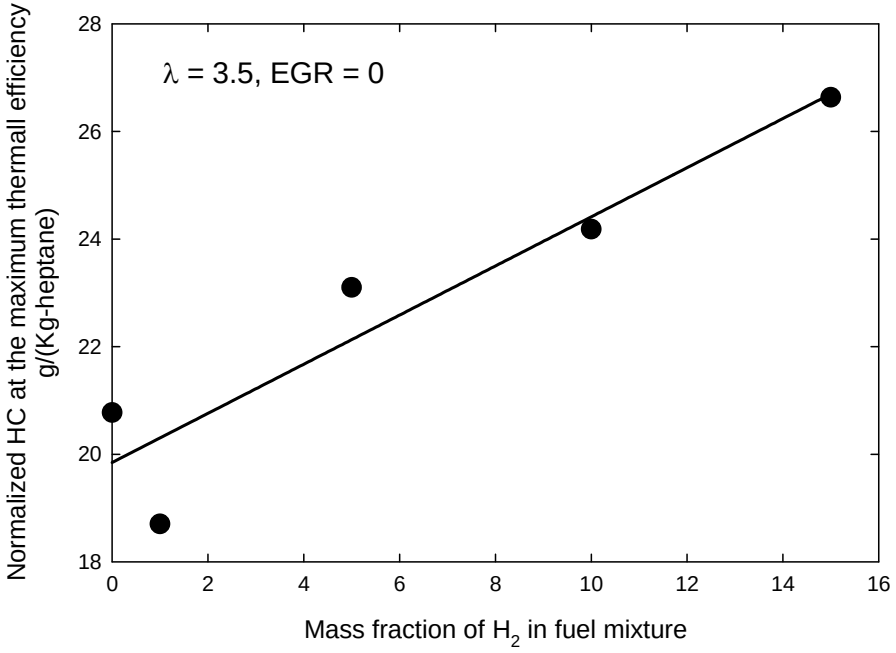
HC Emissions





- Hydrogen enrichment slightly increases HC emissions

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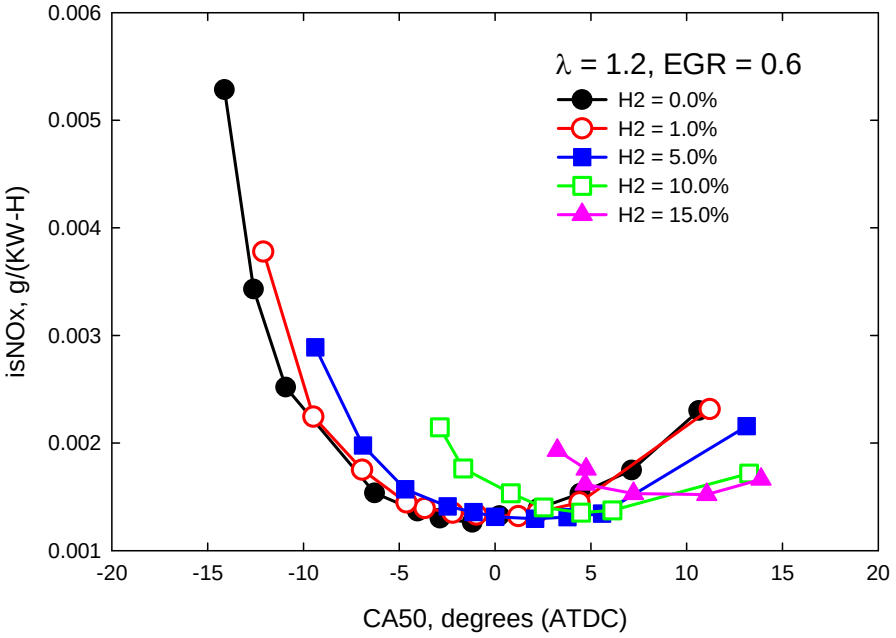
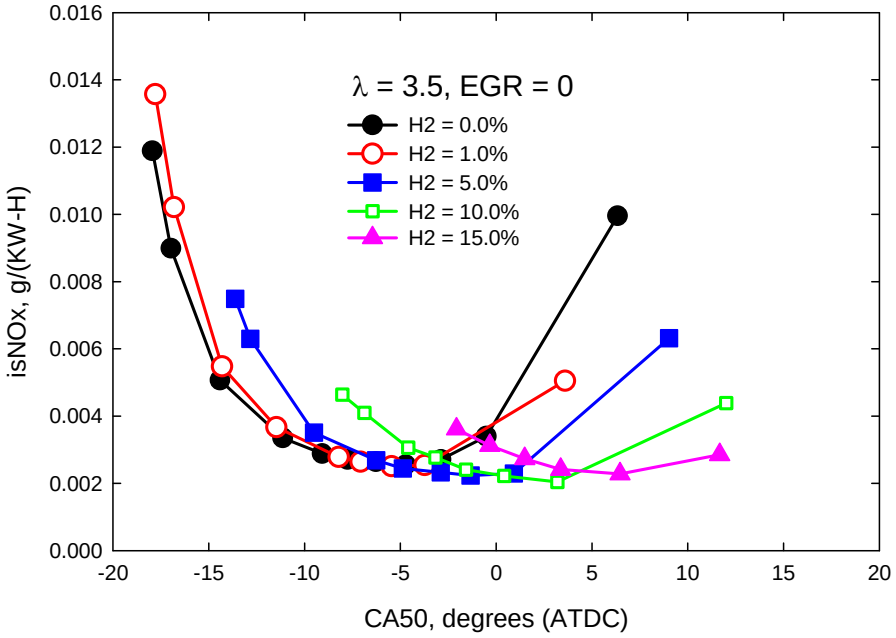
NO_x Emissions





- Hydrogen enrichment does not significantly affect NO_x emissions

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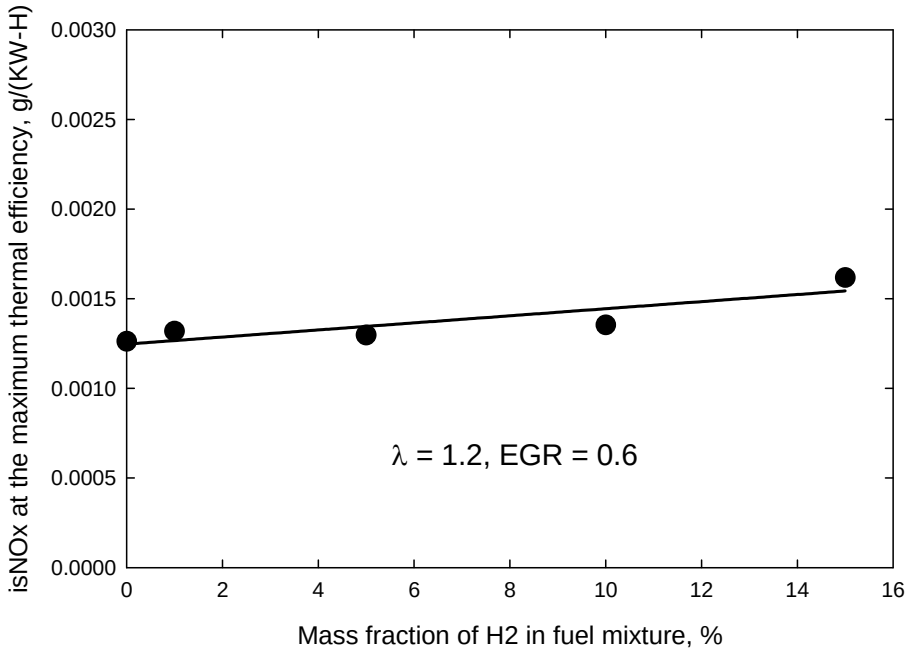
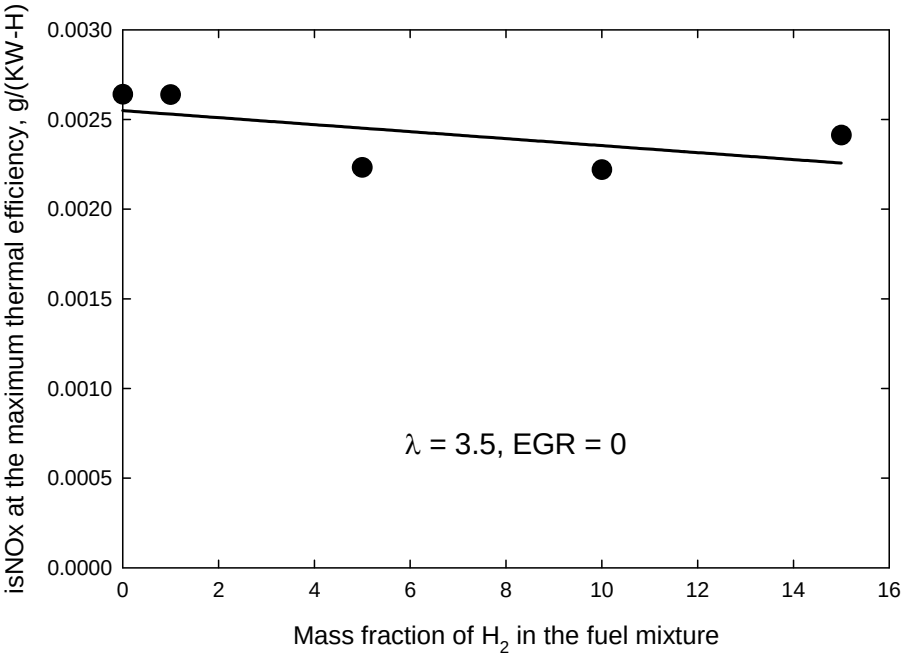
NO_x Emissions





- Hydrogen enrichment does not significantly affect NO_X emissions

Conclusions

- Hydrogen enrichment retards phasing of n-heptane HCCI combustion, and reduces combustion duration
- Hydrogen enrichment increases power output and improves thermal efficiency of n-heptane HCCI combustion
- Hydrogen enrichment improves combustion efficiency
  - reduces CO emissions, but slightly increases HC emissions
- Hydrogen enrichment does not significantly affect NO_x emissions in HCCI combustion

- *Does hydrogen enrichment improves HCCI combustion for all diesel fuels?*

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Thanks!

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