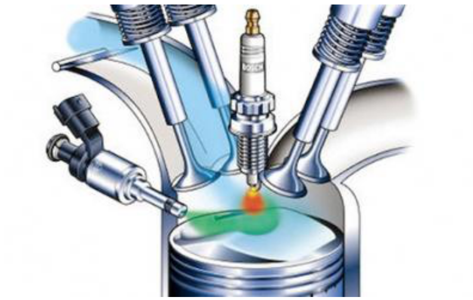
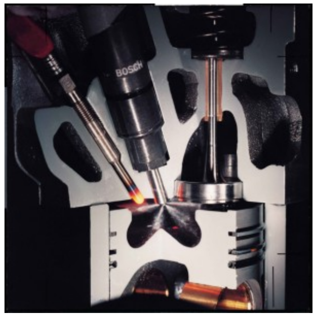
Recent Advances in Internal Combustion Engines

4A13

To SI or to CI ?

	SI	CI
Efficiency	lower	higher
NOx	lower	higher
PM	lower	higher
Cost	lower	higher

Is there something in-between?
Can we combine the advantages?

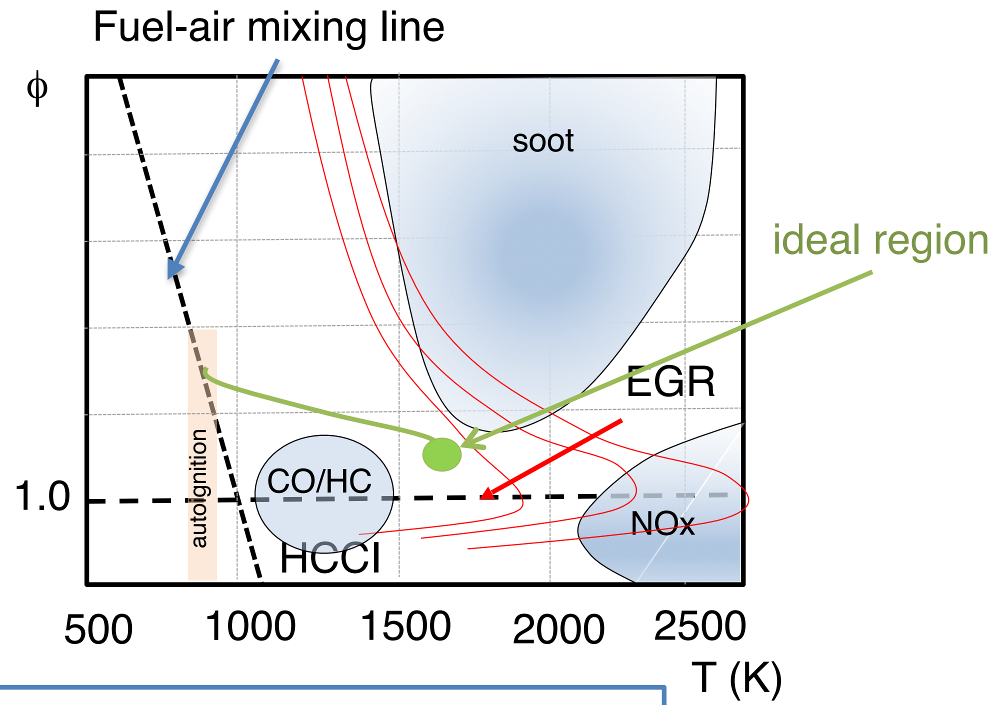
http://www.cleanmpg.com/photos/data/500/di.jpg

Homogeneous charge/partly mixed charge Compression Ignition (HCCI/PCCI)

Homogeneous CCI (HCCI) (late 90s):
- premixed mixture
- CR depends of fuel to autoignite
- load limited to low values (to avoid uncontrolled ignition/high noise/vibration)

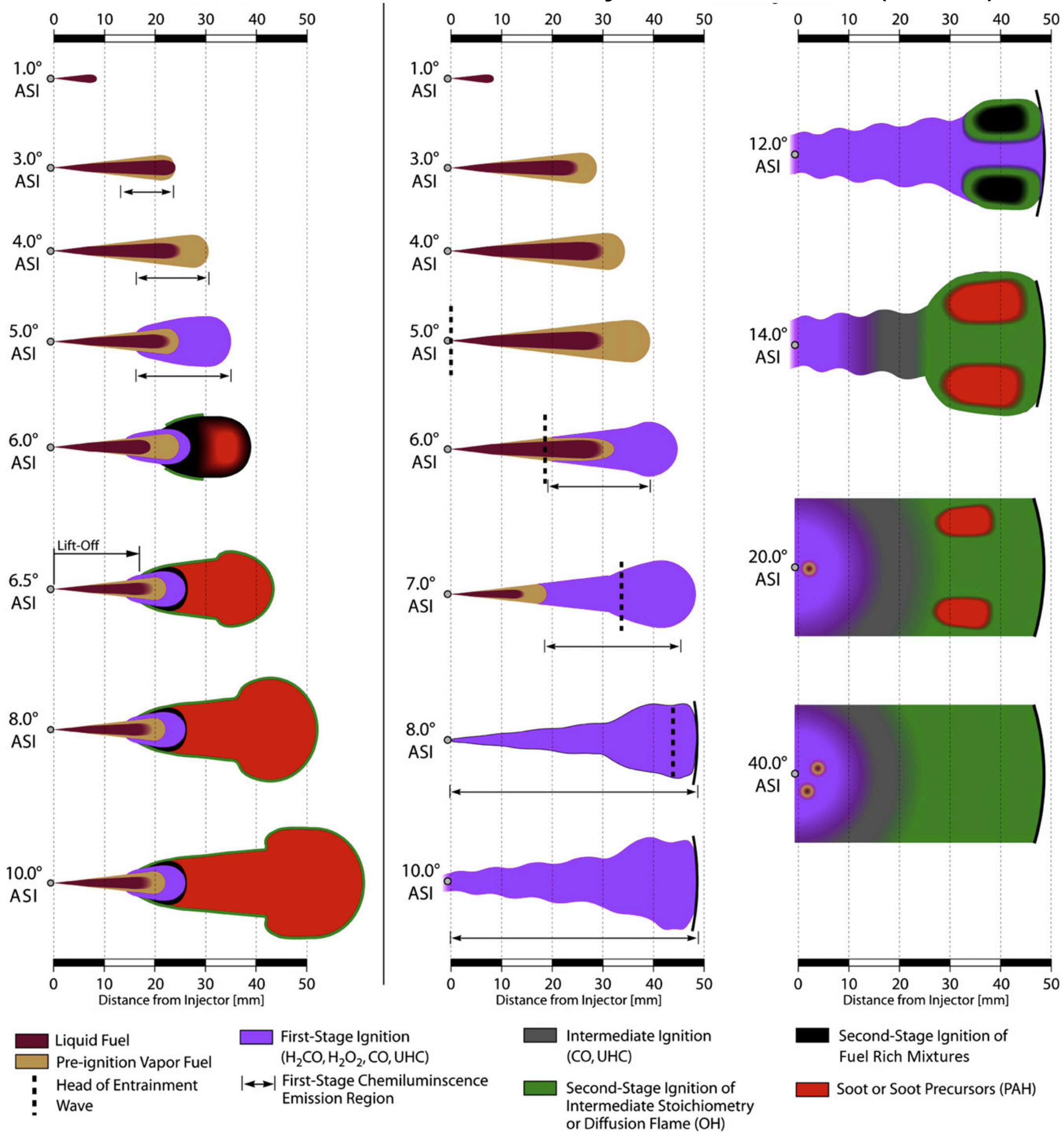
Partially premixed CI (PPCI) PREDIC, UNIBUS, LTC, using early injection or split injection

Partially premixed GDI-CI
- low octane fuel: autoignition at low temps



Goal is to reduce NO, soot emissions by increasing premixing. Constraints are:
(a) the ability to control onset of autoignition at a given time/crankangle to maximize efficiency,
(b) control the rate of combustion to minimize noise, vibration and harshness (NVH)
(c) minimise reaction quench which lead to high CO,HC.

Normal CI   Partially Premixed CI (PCCI)/Low temperature combustion (LTC)



Heavy duty engine, EGR diluted PCCI vs. CI:

Longer time for premixing leads to lower temperatures and lower soot, NO

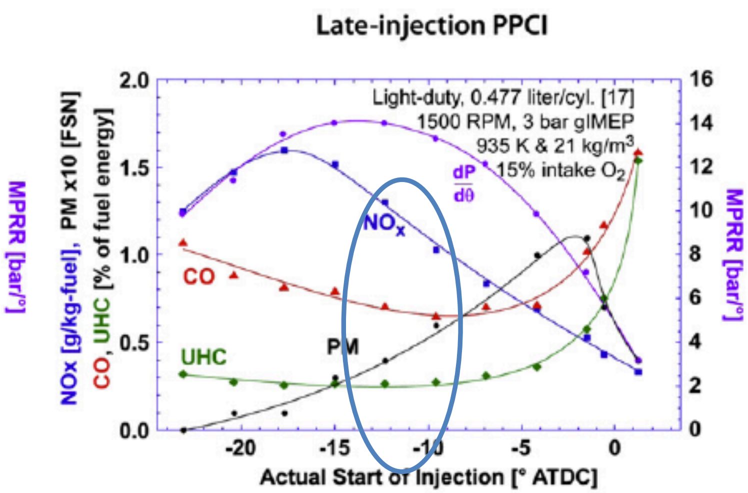
Lower temperatures: risk of high CO, UHC remaining in cylinder

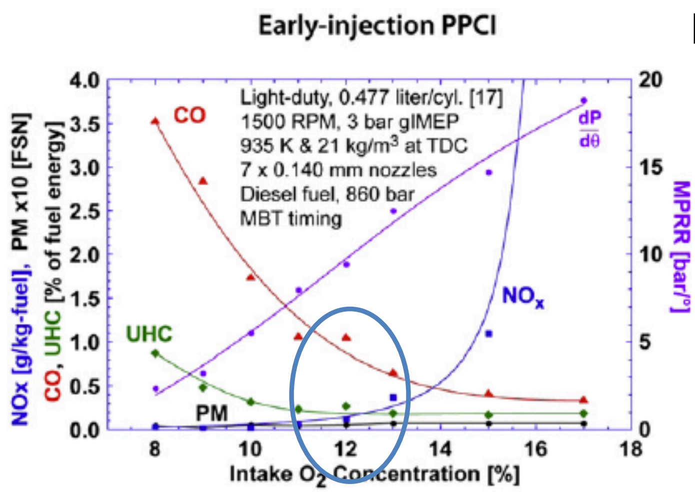
High load: rate of pressure rise may be too high

Emissions PPCI/LTC: Light duty engine

(15% O2)

MBT timing





NO and pressure rise rate too high

PM, CO, HC too high (not enough time to burn)

EGR

CO, HC too high (lost efficiency)

Pressure rise rate too high
NO emissions too high

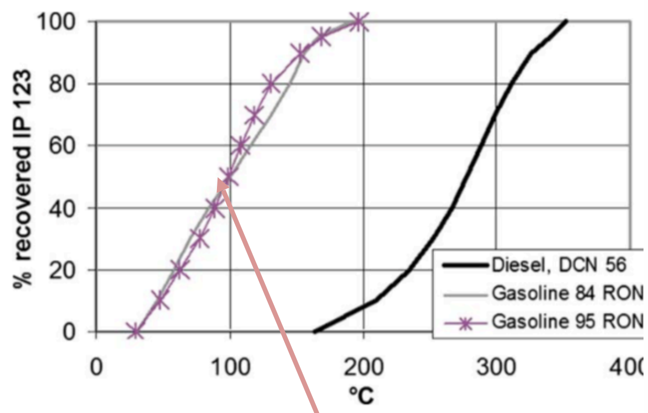
More diffusion-like burning
Overall higher emissions

More premixed
Lower PM and NOx achievable
Acceptable for low loads

Musculus et al., PECS 39 (2013) 246-283

GDI-PCCI gasoline

Distillation curve



Gasoline ON 84 vaporizes promptly compared to diesel: more time for premixing

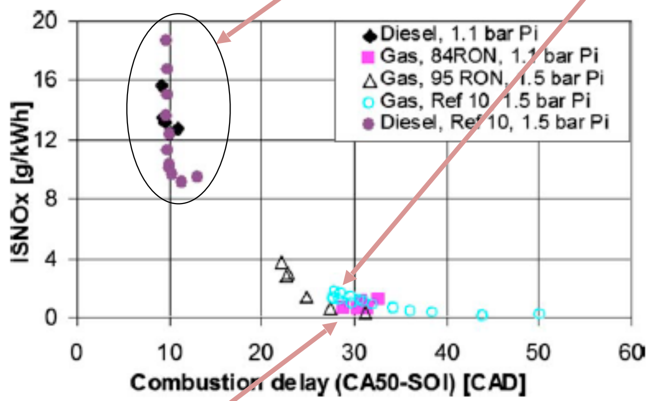
Produces **much less NOx** than diesel at same load

Requires **boosting** and **intermediate CR** to autoignite

Kalghatgi et al, JEGTP 2010, 132 092803-1

Range of delays for diesel: short, so no time for premix

Longer delay for gasoline: more premixing



heated intake 60 C
CR = 16
p_i = 1.5 bar

Fig. 4 ISNO$_x$ versus combustion delay for cases in Fig. 2. Also comparing with data from Ref. [10].

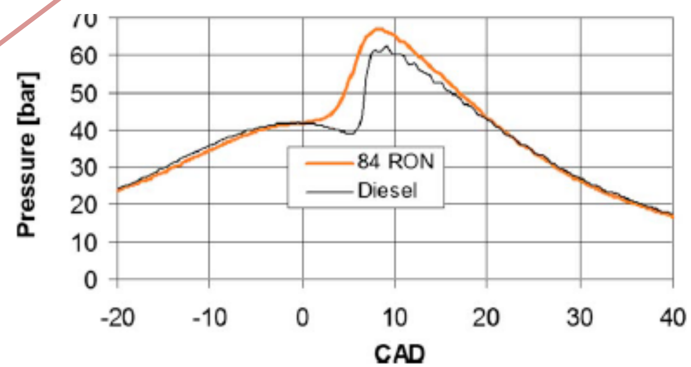


Fig. 7 Pressure and heat release rates at 3.95 bar IMEP for diesel and 84 RON gasoline

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SAE INTERNATIONAL

Pathway to 50% Brake Thermal Efficiency Using Gasoline Direct Injection Compression Ignition

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Citation: Sellnau, M., Foster, M., Moore, W., Sinnamon, J. et al., "Pathway to 50% Brake Thermal Efficiency Using Gasoline Direct Injection Compression Ignition," *SAE Int. J. Advances & Curr. Prac. in Mobility* 1(4):1581-1603, 2019, doi:10.4271/2019-01-1154.

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GDCI

FIGURE 24 Initial $BSFC_{00}$ map for Gen3X GDCI engine using a 500 bar GDi fuel system and a single-stage boost system with a new GDCI-diffusion combustion strategy for high load (full lean operation without EGR).

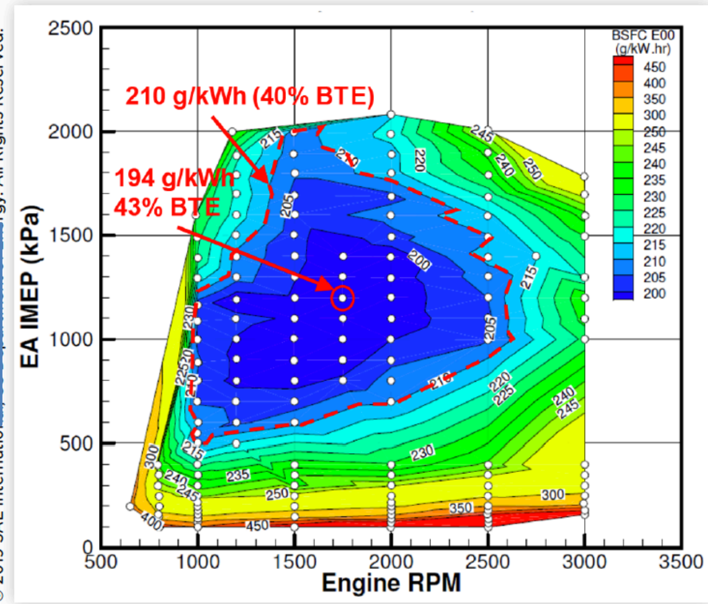
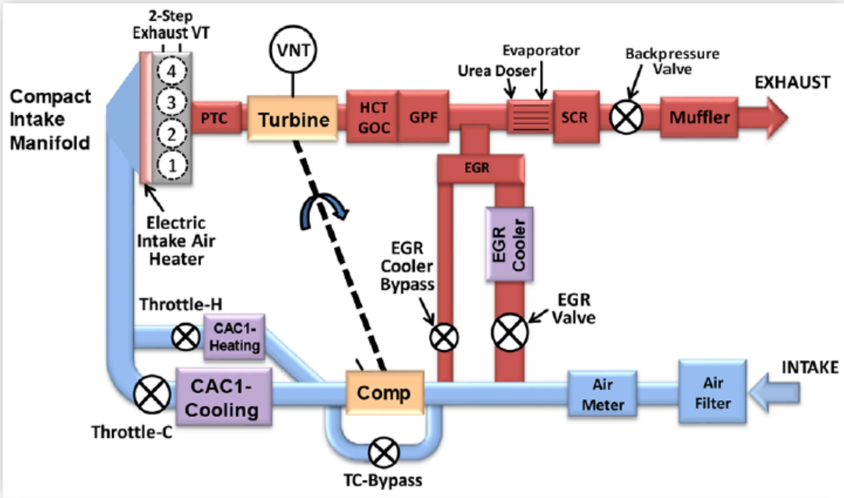
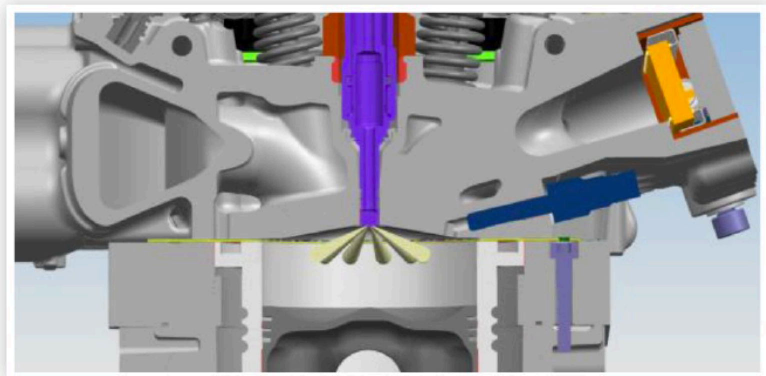


FIGURE 2 Air system for Gen3X engine showing fast air blend system with one heating CAC, one cooling CAC, and two throttles.



NOx less than 0.02 g/kWh and smoke less than 0.08 FSN: lower than engine-out emissions of most gasoline and diesel engines

FIGURE 4 Gen3X GDCI cylinder head.



43% broad peak gasoline operaton low emissions

Summary: advanced concepts in ICEs

- Partially premixed CI (PPCI) or Low Temperature Combustion (LTC) concepts now taking IC engines to diesel like (45-50%) efficiencies at SI like emissions at CRs around 14-16
- Merging of concepts using gasoline for low emissions; operation in multi mode (CI or SI) depending on load.
- Use of more volatile fuels sign as gasoline with lower soot formation tendency
- Concepts involve supercharging using electric storage and/or turbocharging
- Trend varies with vehicle application, but largely combines downsizing/ boosting with compression-ignited direct injection for low temperature, partially mixed, low PM concepts

http://to.eng.cam.ac.uk/teaching/surveys/4A13_Lent.html[a]