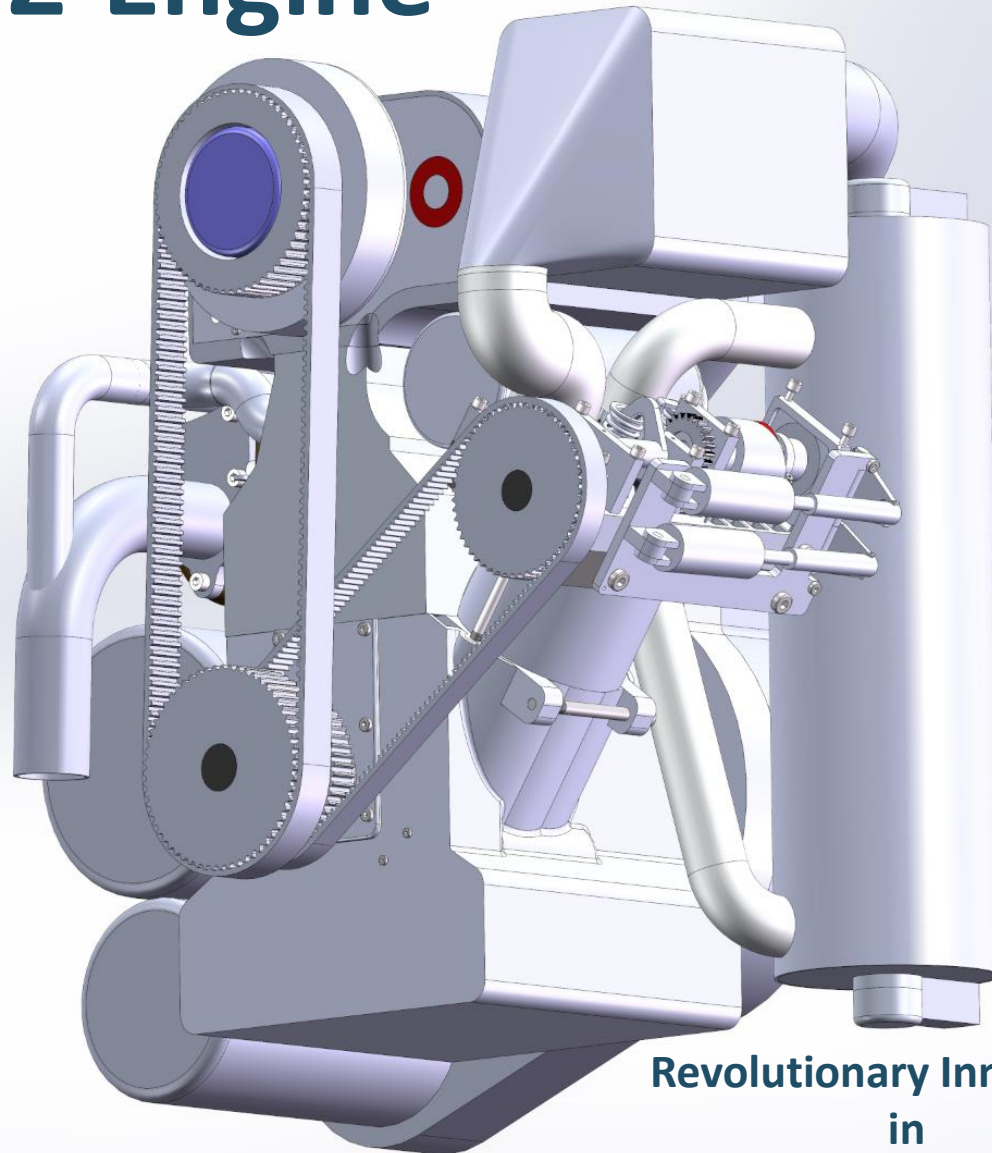


Aumet

The Z* -motor company

Z-Engine



**Revolutionary Innovations
in
Internal Combustion Engine**

Vehicle unit sales price & profit, Case VW

Case VW:

<https://annualreport2018.volkswagenag.com>

- 10,101,297 passenger cars @ 2018
- Sales Revenue €160.8 billion
- Operating Result €9.22 billion
- Simplification: all the sales & profit is done with vehicles → average sales price & eventually average cost / vehicle can be calculated
- → average sales price / vehicle = €15900
- → average operating result / vehicle = €912
- → Sales Revenue – Operating result = €151.6B
 - → average cost /vehicle = €15005

ADJUSTMENT OF THE PASSENGER CARS BUSINESS AREA

€ million	Actual 2018	Actual 2018 after adjustments ¹
Sales revenue	160,802	172,678
Operating result	9,220	10,000
Operating return on sales (%)	5.7	5.8

¹ Passenger Cars Business Area including the Volkswagen Commercial Vehicles brand in accordance with the reporting from January 1, 2019.

VOLKSWAGEN GROUP DELIVERIES¹

	2018	2017	%
Passenger Cars	10,101,297	10,038,756	+0.6
Commercial Vehicles	732,715	702,778	+4.3
Total	10,834,012	10,741,534	+0.9

¹ Deliveries for 2017 have been updated to reflect subsequent statistical trends. The figures include the Chinese joint ventures.

<https://europe.autonews.com/sales-segment/automakers-fight-rescue-small-cars-extinction-eu-rules-bite>

Car engine cost analysis

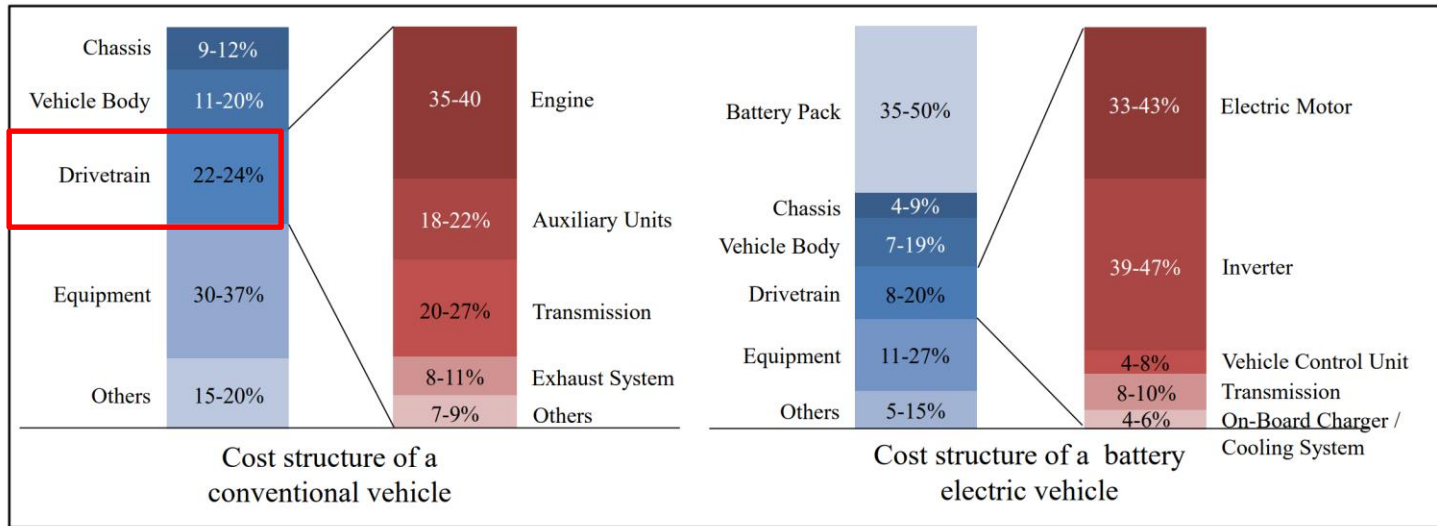


Figure 1: Cost structure of an ICEV and a BEV [KAM13]

- Here it is assumed, that cost structure of conventional vehicle includes all the costs (e.g. segment others...)
- Case VW: Drivetrain average cost: $23\% * 15005 = \text{€}3451$
- Engine average cost: $37.5\% * \text{€}3451 = \text{€}1294$

Background information for analysis

Automakers fight to rescue small cars from extinction as EU rules bite

<https://europe.autonews.com/sales-segment/automakers-fight-rescue-small-cars-extinction-eu-rules-bite>

“... an automaker's smallest, lightest car -- the car that traditionally helped lower the company's average CO2 -- no longer offsets the higher emissions of bigger cars “

"Ironically the smaller vehicles are toughest to reduce CO2 in,"
Ford of Europe Chairman Steve Armstrong told *Automotive*

Looking at the average cost of minicars and small cars, it's clear they are not well placed to absorb the extra cost. Statistics from JATO show that the average retail price of cars registered in Germany, Spain, France and Italy in the first quarter of 2018 was 14,152 euros for minicars and 17,459 euros for small cars. Bernstein estimates that automakers make "only a few hundred euros" gross profit per car on small cars.

Another reason why small cars are going to get more expensive to produce -- even if they keep their combustion engines -- is because of tougher standards for oxides of nitrogen (NOx) that take effect in September 2020. Ford's Armstrong estimated that bringing tailpipe emissions to the Euro6d Temp standard will cost about 2,000 euros whether the car has a diesel or gasoline engine. Also affecting all cars, small to large, are EU requirements to add a raft of mainly camera-based safety equipment starting in 2021.

Cutting CO2 emissions by means of partial electrification such as adding mild-hybrid, full-hybrid or plug-in hybrid technology is one option, but this solution won't be economically viable for many brands. A 48-volt mild-hybrid option adds 600 euros to 1,000 euros per car, according to Bernstein analysis, a full hybrid costs almost 2,000 euros while a plug-in hybrid adds up to 5,000 euros.

Ford:

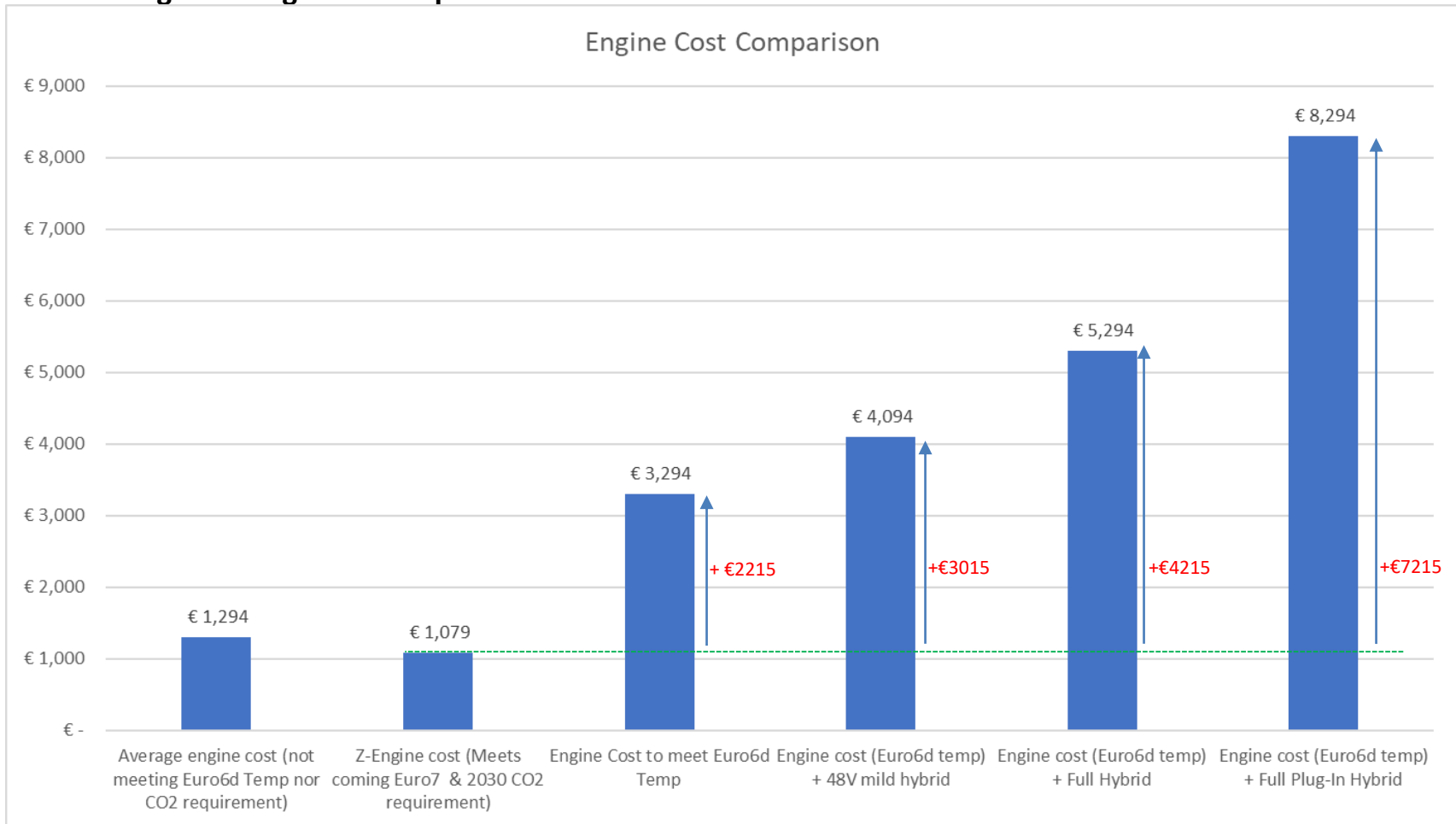
- +2000€ for Euro6d Temp, both diesel & gasoline

Bernstein:

- Mild-Hybrid: +600€...1000€
- Full-Hybrid: + 2000€
- Plug-in Hybrid: up to +5000€

Z-engine manufacturing cost estimate vs VW average Engine

- Z-Engine cost is derived from VW average engine cost, then Z-Engine cost is compared to average VW engine developments with both Ford & Bernstein data



Remember: average estimated operating result / vehicle = €912

Note: Euro7 not yet defined, but strong belief that Z-Engine meets this coming standard

Thank You!

Contact Information for Aumet Oy:

Timo Janhunen

Managing Director

Timo.Janhunen@aumet.fi

+358 40 502 6257

<http://www.aumet.fi/index.php>

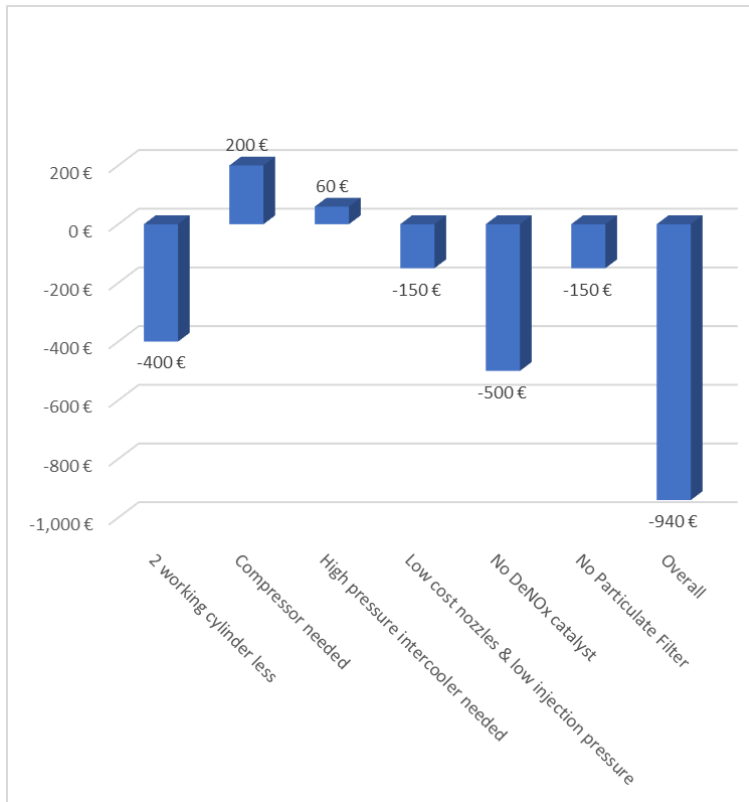
Additional material

-1st generation manufacturing cost analysis

Links:

<https://www.researchgate.net/publication/260339436> An Overview of Costs for Vehicle Components Fuels and Greenhouse Gas Emissions

Manufacturing costs of the Z-engine compared to a 4-cylinder turbodiesel engine equipped with Common Rail + DeNOx-catalyst + oxicat + particulate filter



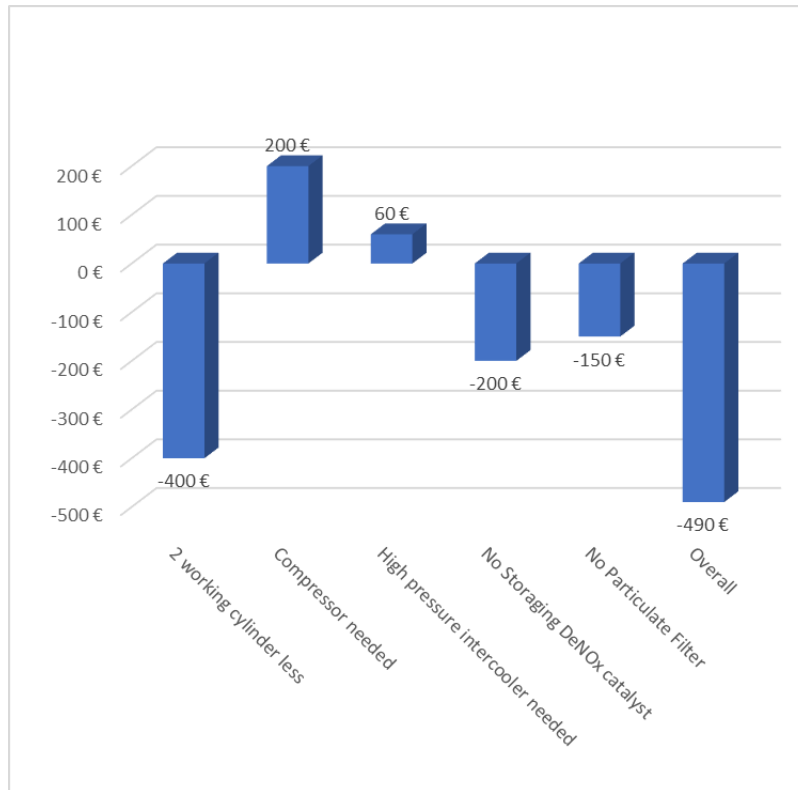
- 2 working cylinder less = - 400 €
- Compressor needed = +200 €
- High Pressure Intercooler needed = +60€
- Low injection pressure, low cost nozzles = - 150 €
- No DeNOx catalyst (SCR)* = - 500 €
- No particulate filter = - 150 €
- Overall = - 940€

Together = - 940 € lower production costs per engine!

*: Latest TDI:s injection pressure up to 2500bar, max pressure in Z-engine injection is ~1100bar (optimization parameter)

** : latest trend among manufacturers is to have 2 x SCR catalysts to remove NOx emissions fully

Manufacturing costs of the Z-engine compared to a 4-cylinder gasoline turboengine equipped with gasoline direct injection, particle filter, oxycat and storing DeNox catalyst



- 2 working cylinder less = - 400 €
- Compressor needed = +200 €
- High pressure intercooler needed = +60€
- No storing DeNox catalyst = - 200 €
- No particulate filter = - 150 €
- Overall = - 490€

Together = - 490 € lower production costs per engine!