

## Volkswagen Emissions Scandal

We are going to continue our ethics discussion with Volkswagen, which is highly germane to software engineers.

### Context

There is some political will to reduce CO<sub>2</sub> emissions in response to climate change. Diesel produces maybe 10–20% fewer CO<sub>2</sub> emissions than gasoline per distance travelled, and more torque, but also more nitrous oxides (NO<sub>x</sub>) and more fine particulate matter (also known as PM2.5, or soot).

Historically, diesel has been popular in Europe (around 50% of the car market) but not in North America (around 3% of the car market, was growing until the scandal broke). Yet people had been observing higher soot emissions in cities, and the Paris mayor, Anne Hidalgo, had called for diesel bans or buybacks, even prior to the scandal. As of October 2018, diesel bans are coming in German cities: Hamburg, Berlin, Stuttgart, Frankfurt.

### The Issue

Volkswagen's CEO had a stated objective of leading VW to be the biggest car manufacturer in the world. However, to sell cars in the US, they had to meet new, stricter NO<sub>x</sub> limits. (NO<sub>x</sub> aggravates asthma, among other ill effects). Since 2008, they have been advertising “clean diesels” which allegedly meet the new limits.

Catalytic converters reduce NO<sub>x</sub> levels in gas engines, but don't work for diesel engines. Instead, the usual solution is to use “selective catalytic reduction”, which injects urea into the combustion mixture. But the car then needs a urea tank and refills.

Or, in an illustration of a classic engineering tradeoff, the manufacturer can sacrifice either power or fuel efficiency for cleaner emissions. Since it's 2016, the tradeoff is controlled by software running in the engine control unit.

### The Discovery

Before the scandal broke, experts had been quietly suspicious about the lack of an urea tank<sup>1</sup>; and customers had noticed soot on their cars.

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<sup>1</sup>Afterwards, Prof. Dudenhofer, director of the Center for Automotive Research at the University of Duisburg-Essen, said “They must have known that it's impossible, or else it's not possible they have degrees as engineers.”

In any case, it was odd that the US cars satisfied stronger standards than those in Europe. The International Council on Clean Transportation (ICCT), an engineering-heavy thinktank, wanted to know why. It commissioned engineers at West Virginia University to investigate.

VWU engineers Marc Besch and Arvind Thiruvengadam performed in-lab and on-road testing of both VWs and BMWs. The in-lab tests, under controlled conditions, achieved the advertised emissions targets. But once they brought the VW cars on the road, they found NO<sub>x</sub> emissions that were 5× to 35× over targets. Not so for the BMWs. They presented their work at the *Real-World Emissions Workshop*, an academic conference, in May 2014.

## Regulators and Consequences

The US Environmental Protection Agency started quietly investigating soon afterwards. Presumably after some period of discussions with Volkswagen, they published a Notice of Violation in September 2015, at which point the scandal made the news (see below). Although Volkswagen owned up to the cheating (at some level) fairly early, it continues to face massive consequences, including a steep decline in sales, a change in CEO, a drop in stock value, and even raids of their offices.

## Engineering Analysis

### How did this work?

- it's all software-controlled;
- when the software detects test conditions (no steering/fixed speeds/etc), it switches into so-called “dyno calibration” mode.
- fewer emissions but also less torque and less efficiency.
- must have been put in by software engineers working with the engine designers.

### How did this happen?

- regulators set an objective testing scheme that was possible to hack (is being improved);
- fundamentally, there is an engineering tradeoff: urea tank vs targets for torque and fuel efficiency.
- Upper management set specifications which were not achievable; they attempted to blame rogue engineers; VW is an engineering-focussed organization, not credible.

## References

I've only provided a superficial summary of the situation. There is a lot of good long-form journalism on this topic. Good to read over Christmas. Most links retrieved 21 November 2016.

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