



Formulating lubricants for a digital and sustainable future

Accelerating learning to support energy transition
in an era of growing complexity

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Layout

Accelerating learning to support energy transition in an era of growing complexity



**Lubricant
development is
becoming more
complex**



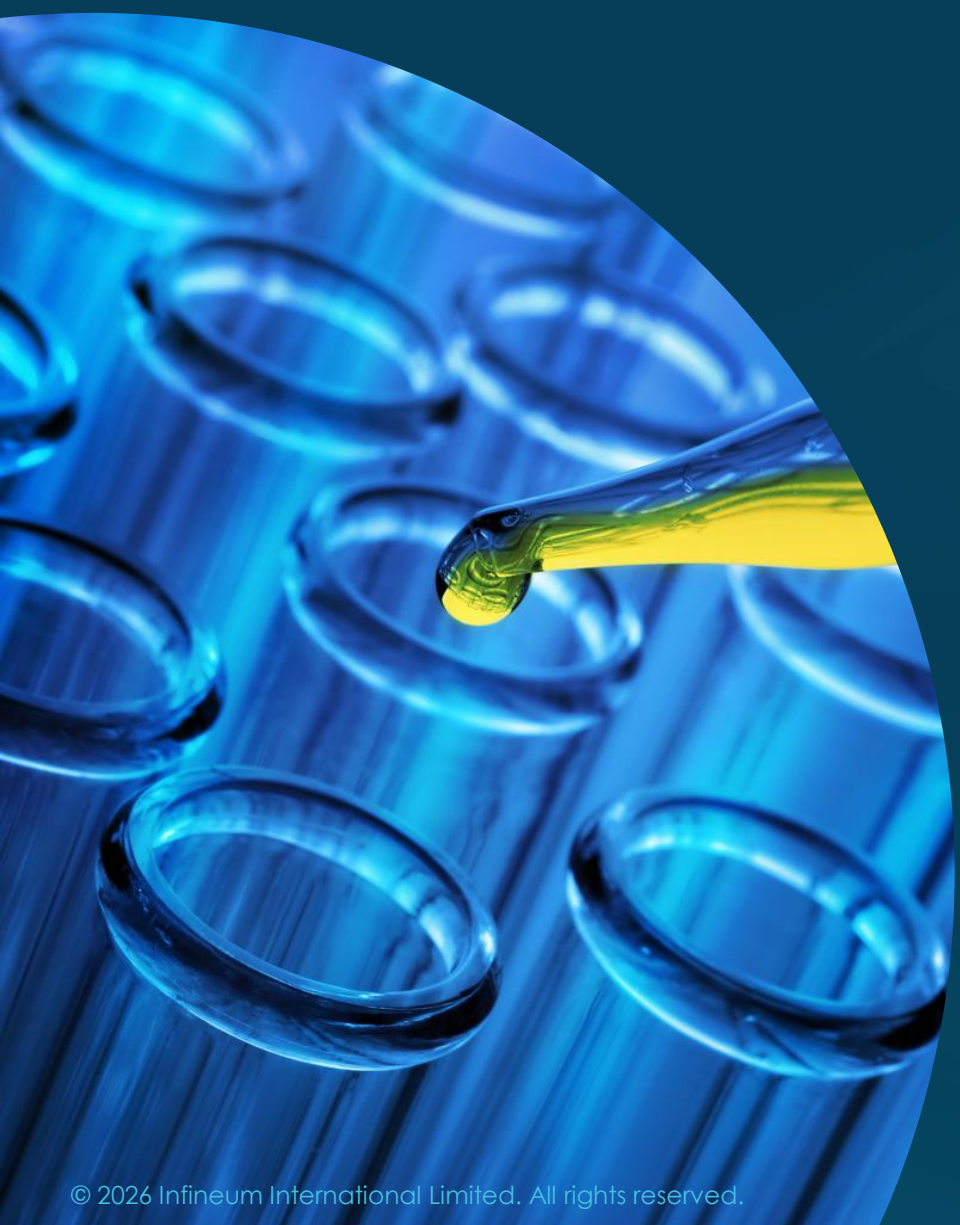
**Traditional
development
faces growing
bottlenecks**



**Digital
+ AI can
accelerate
learning**



**Complexity is
rising...
but so is
opportunity**



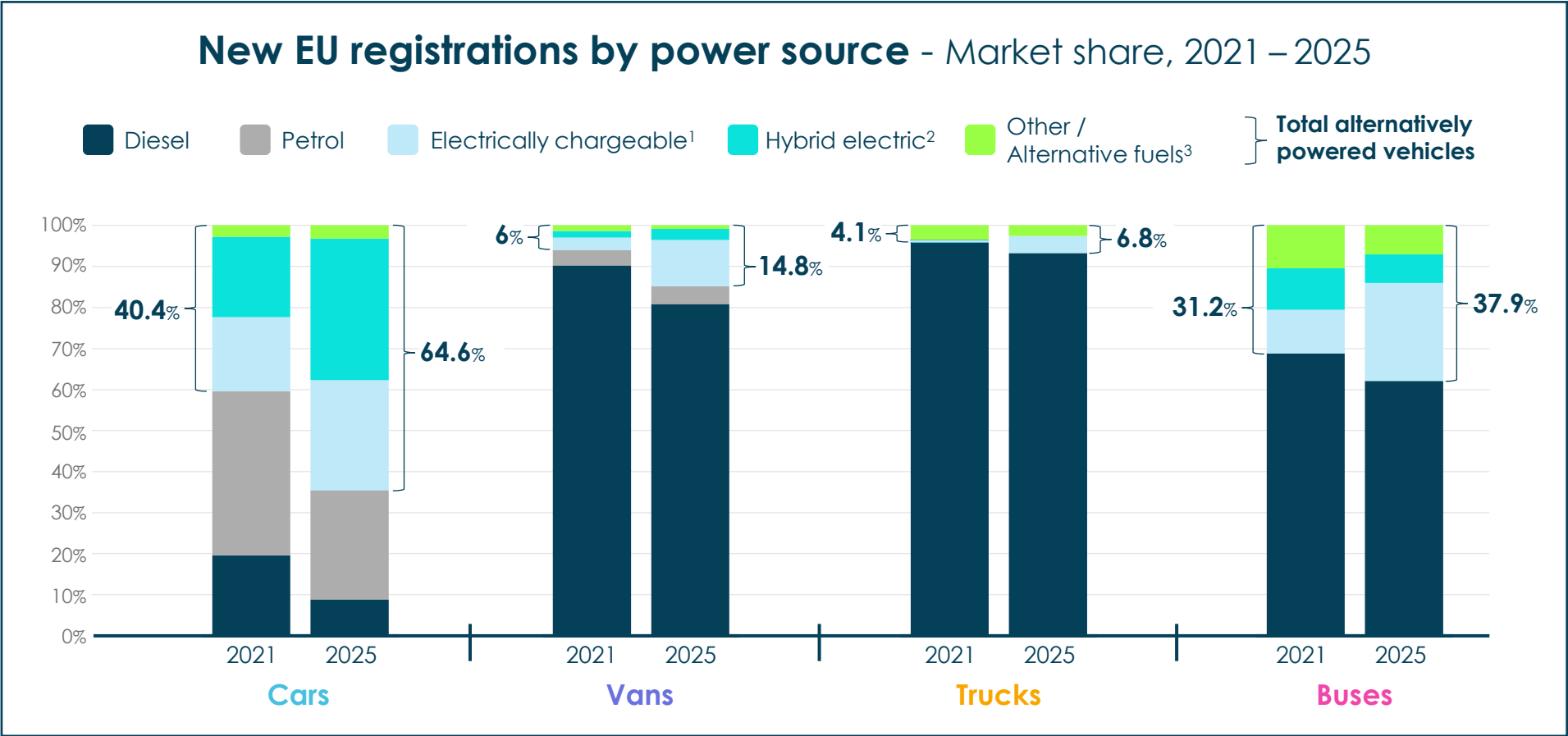
Today's complex lubricant market:

Traditional development cycles are under pressure as lubricant performance requirements become **more complex, more connected** and **more time-sensitive**

The market is fragmenting, increasing formulation complexity

Powertrain diversity is increasing, whilst the installed fleet continues to age.

The lubricant industry must support multiple technology pathways, advanced new platforms, and older vehicles all at the same time.



Source: ACEA

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Vans = Light commercial vehicles up to 3.5t
Trucks = Medium and heavy commercial vehicles over 3.5t
Buses = Buses and coaches over 3.5t

1. Includes battery and plug-in hybrid vehicles
2. Includes full and mild hybrids
3. Includes natural gas, LPG, ethanol, hydrogen and fuel-cell electric vehicles

A circular inset image on the left side of the slide shows a long-exposure photograph of a multi-lane highway at night. The image captures light trails from vehicles, with white lines for lane markings and various colored streaks (red, blue, white) representing taillights and headlights. The perspective is from an elevated position looking down at the road.

What does this mean for us
as lubricant developers?

We are now operating in a
market with ever
**rising complexity in additive
development**

Additive development is becoming multi-objective systems optimisation

The formulation window is being compressed by **multiple performance requirements at the same time.**



Additional constraints and objectives:

- LSPI
- Extended drains
- Material compatibility
- Value to Cost
- REACH / Chemical toxicology / Labelling regulation
- Hybrid duty cycle
- Sustainability
- New fuels



How does lubricant development support sustainable transportation and energy transition?

An increasingly complex landscape of ICE fuels

leading to new challenges for the lubricant

An increasingly complex landscape of ICE fuels



A complex landscape of ICE future fuels

- lubricant compatibility needed across powertrains and fuels



Fossil fuels

Gasoline | Diesel



Fossil-based alternative fuels

Liquid natural gas
Liquid petroleum gas



Bio-fuels

Ethanol

Fatty acid
methyl ester

Hydrogenated
vegetable oil



Carbon-neutral fuels

Methanol Ammonia
Hydrogen Synthetic /
e-fuels



Regional variation in uptake and availability

An increasingly complex landscape of ICE fuels

Lubricants for H2ICE

- new challenges for the lubricant



Pre-ignition

Primary formulation
defining concern



**POTENTIALLY
PERFORMANCE
ENABLING**



Water management

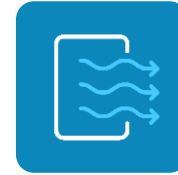
Hydrogen combustion
generates **four times
more water** than diesel

*Accumulation in oil varies
across application*



Durability & wear
may differ from
conventional fuels

*Lubricant assessment
relies on access to
commercial or pre-
commercial
hardware*

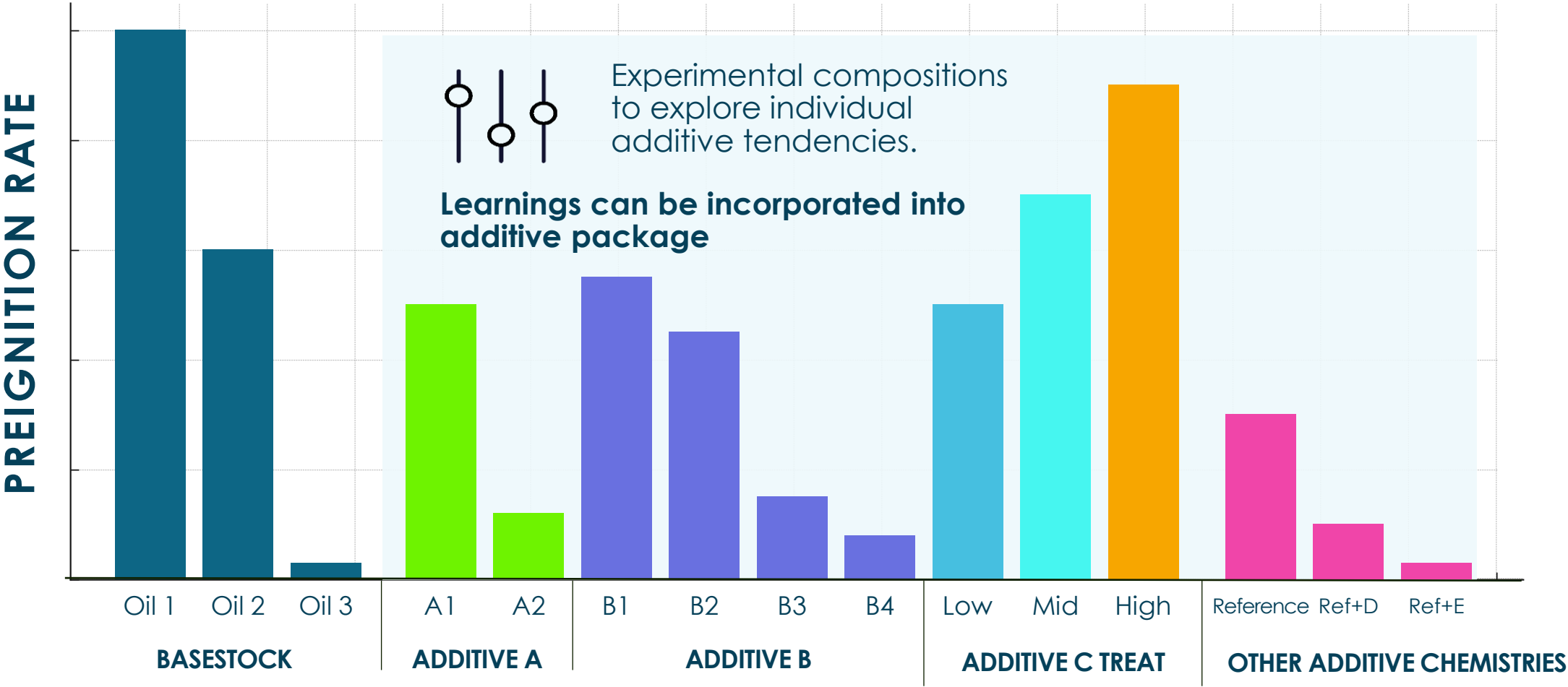


**After Treatment
Compatibility**
critical to H2ICE
acceptance

*H₂ combustion still
generates NO_x*

Pre-ignition – lubricant effect

- a broad database generated



Multiple parts of the lubricant formulation have been found to impact pre-ignition rate

A circular inset on the left side of the slide showing a close-up, high-contrast image of a microchip or circuit board with glowing blue and white points of light.

How do we face all
these challenges?

**Harnessing
digital tools and AI**
to increase learning
efficiency

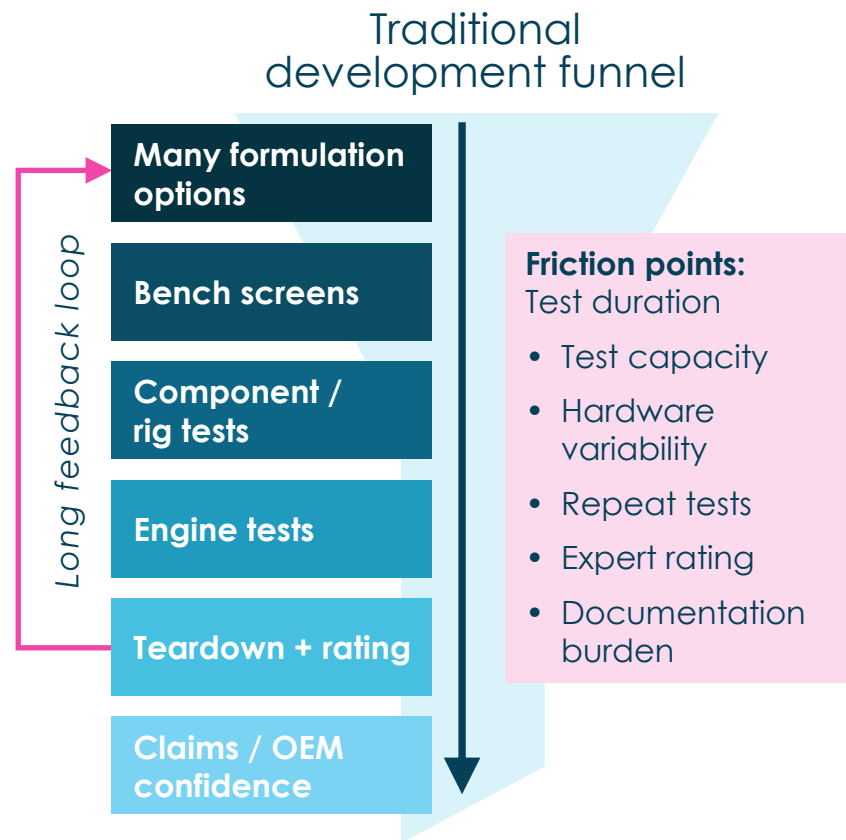
The development bottleneck

- tests, time, data...

The issue is validation bandwidth:

The industry **can** generate formulation options.

The constraint is proving performance with enough speed, repeatability and confidence.



- Insight is generated sequentially
- Learning is tied to each individual test cycle

Sequence IIIH example

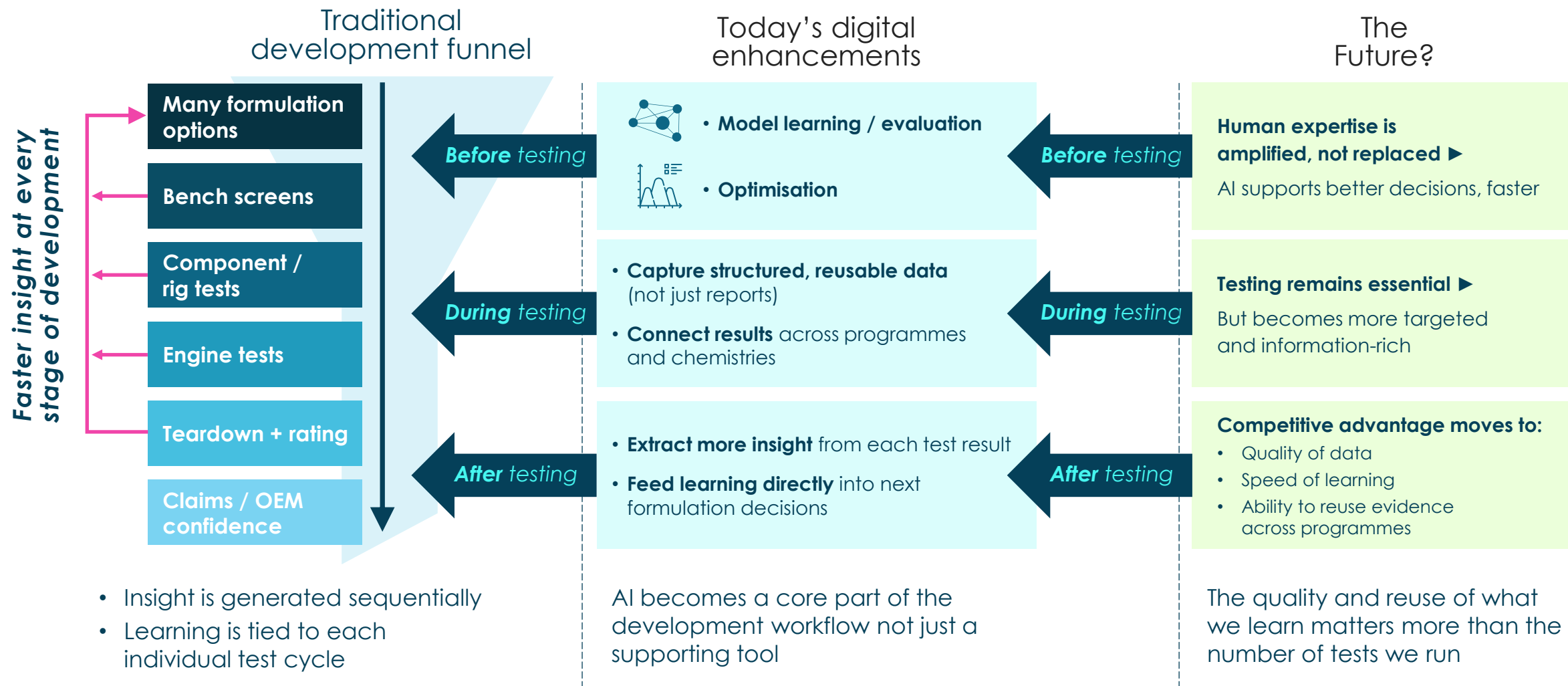
90 hours engine operation

+ oil sampling
+ engine disassembly
+ piston deposit / varnish rating

= one slow, high-value learning cycle

Digital tools transform how we learn from testing

- not only how fast



Digital tools: machine rating

- Piston Cleanliness concept

AI Agent – ColorRatingBot (Pixel by Pixel)

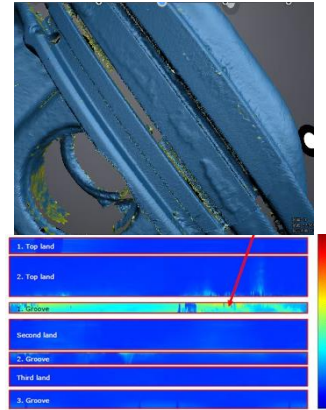


ColorRatingBot Scale with Hex Codes

1	2	3	4	5	6	7	8	9	10
#2B1F18	#40261D	#61271B	#8F4324	#A16036	#B27B45	#BC9460	#B9915E	#D1BD9A	#CECBC6



3D scanning



carbon deposit
(volume)

varnish/lacquer
(discoloration)

Sequence IIIH example

90 hours engine operation

- + oil sampling
- + engine disassembly
- + piston deposit / varnish rating

= one slow, high-value learning cycle

A circular inset image on the left side of the slide showing a close-up of a microchip with glowing blue light patterns.

What is enabling digital, AI
development and adoption?

**Powering the growth of
data centers and AI:**
new requirements and
opportunities for OEMs
and lubricant marketers

Power engines for reliable and fast response

- new requirements and opportunities for OEMs and lubricants



Data center power demand is growing faster than the grid expansion, shifting focus from the grid to the **“Power-first” imperative:**

Demand for secure, reliable, on-site (back-up) power generation



When AI model enters learning mode, power consumption spikes instantly

OEMs develop power generation engines capable of reaching full output within seconds



Lubricant demand expected to grow in both volume and premium synthetic value

Lubricant demand in on-site power gen. equip. in data centers grows 4x btw 2025 and 2035 (Vs 1.2x of the remaining sectors)



Where to play and how to win?

Regional concentration in NA and AP mainly (but Italy/EU growing fast)

Demand growth boosted by **“complete offering”** (immersion cooling, power lubes...) and **OEMs partnership**

Key takeaways

Accelerating learning to support energy transition in an era of growing complexity



Lubricant development is becoming more complex

Driven by hardware, regulation, new fuels and sustainability



Traditional development faces growing bottlenecks

Time, cost, test capacity and variability



Digital + AI can accelerate learning

When built on high-quality data and expert judgement



Complexity is rising... but so is opportunity

Lubricant for H2ICE and new fuels, powering data centers



Formulating tomorrow together

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