New electric locomotives for the UK

- TRAXX UK with Last Mile feature
- Technology outlook

The 20th Annual Rail Freight Group Conference

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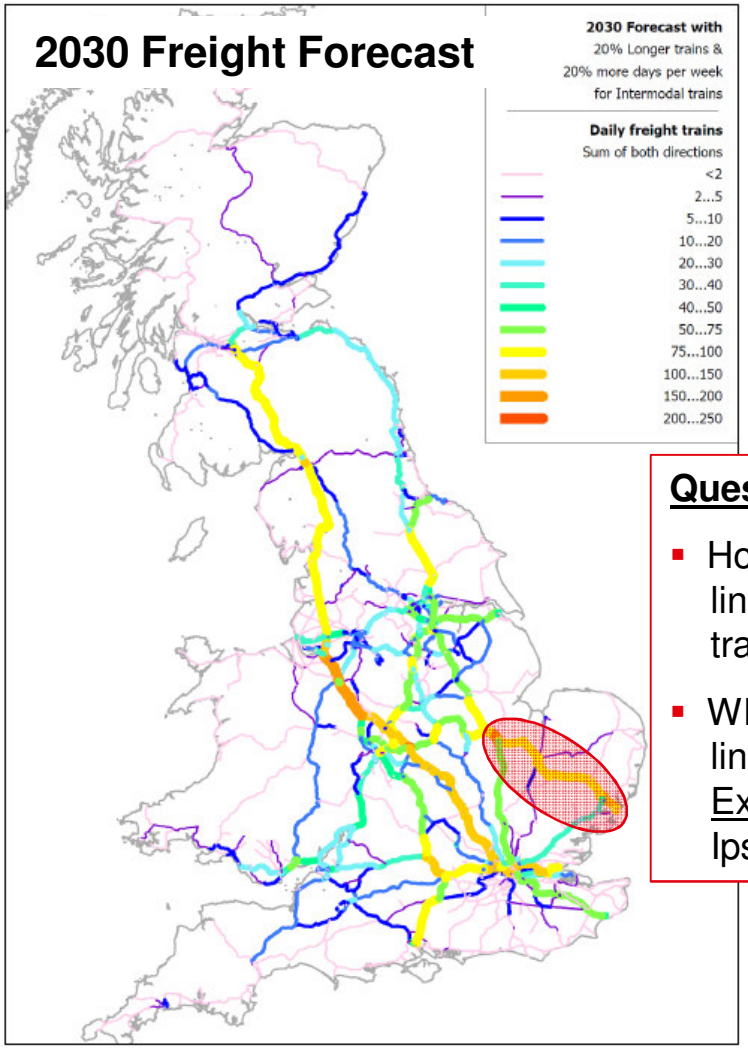
Freight traffic 2030 forecast* overlaps with the existing and future electrified lines – but only partially.



Questions:

- How can the electrified lines be used for freight traffic?
- Where are the missing links for freight?
  Example: Felixstowe – Ipswich – Peterbough

*) Rail freight demand forecasts to 2030, MDS Transmodal Limited, October 2011

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A look across the Channel: Electric traction is dominant for freight throughout Europe, also on major corridors

Typical speeds for freight with E-locos:

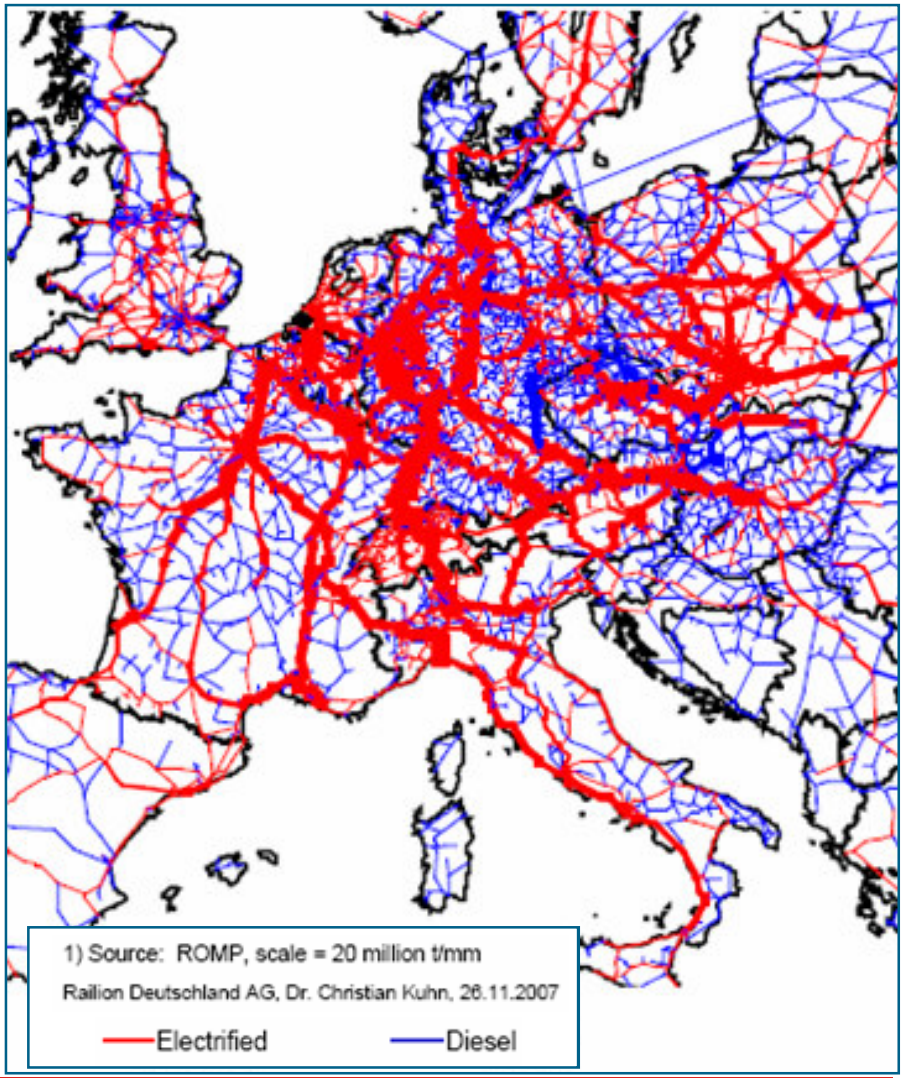
- 80 – 120 km/h

Typical trains:

- One loco + 1'600 tons on 12‰ (1:83)

- Two locos + 3'400 tons on 12‰ (1:83)

- **Future:** 2'200 ton intermodal trains (matching the max train lengths of 700 to 750 m)



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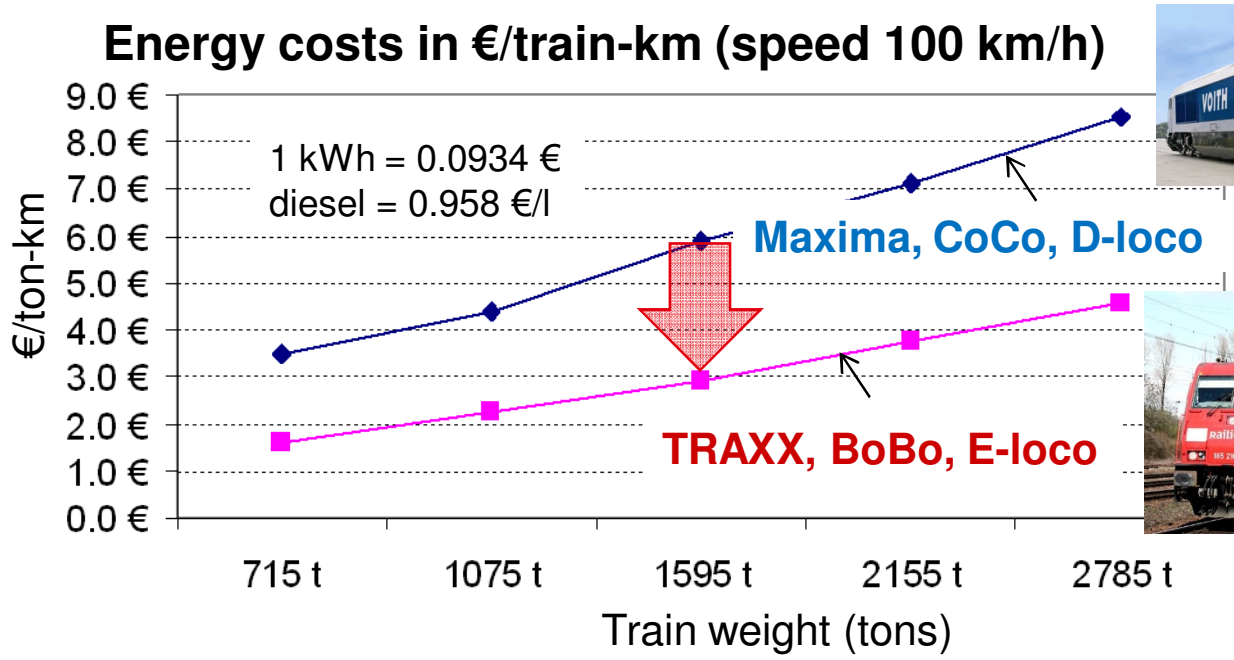
Long haul diesel traction is not competitive in Germany

Energy costs for diesel locos are 2x higher than for electric locos



- Diesel traction has 2x higher energy costs for the same train load
  - Maxima*: 3'600 kW diesel → 2'900 kW at the wheel
  - TRAXX: 5'600 kW at the wheel
- Δ cost for diesel loco**: approx. 300 k€/loco/year

*) The Maxima is one of the most powerful diesel locos in Europe

**) With 1'595 ton train weight, 100'000 km/year

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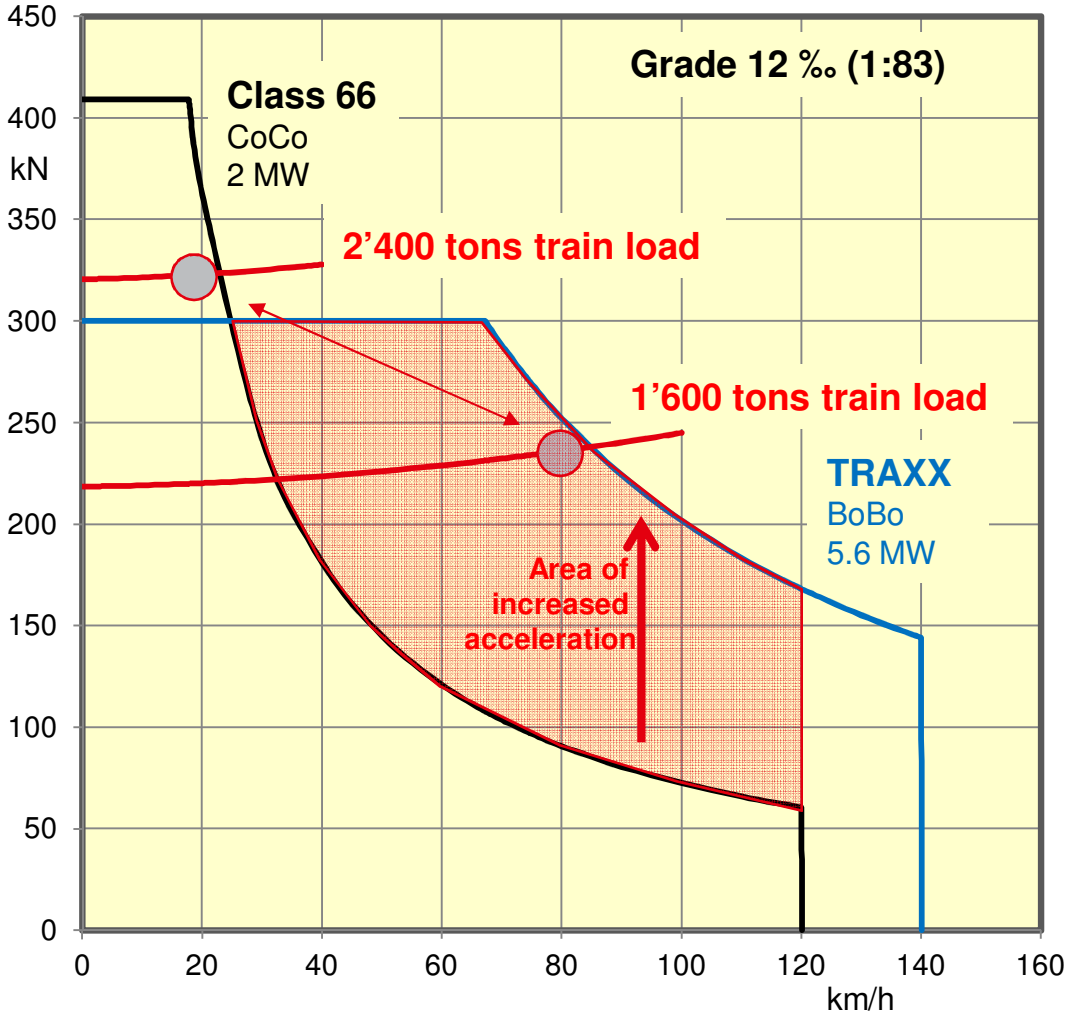
E-locos have much more power at the wheels and are suited for mixed freight and high speed passenger traffic



- **Electric locos**
  - 4-axle configuration
  - 5'600 kW at the wheels
  - → Operate at 80 – 120 km/h also on grades
  - → Suited for mixed traffic with passenger trains
- **Diesel locos**
  - 6-axle configuration
  - Approx. 2'000 kW at the wheels
  - → Operate at lower speeds, particularly with heavy loads and on steep grades
  - → Require dedicated tracks if speeds are low

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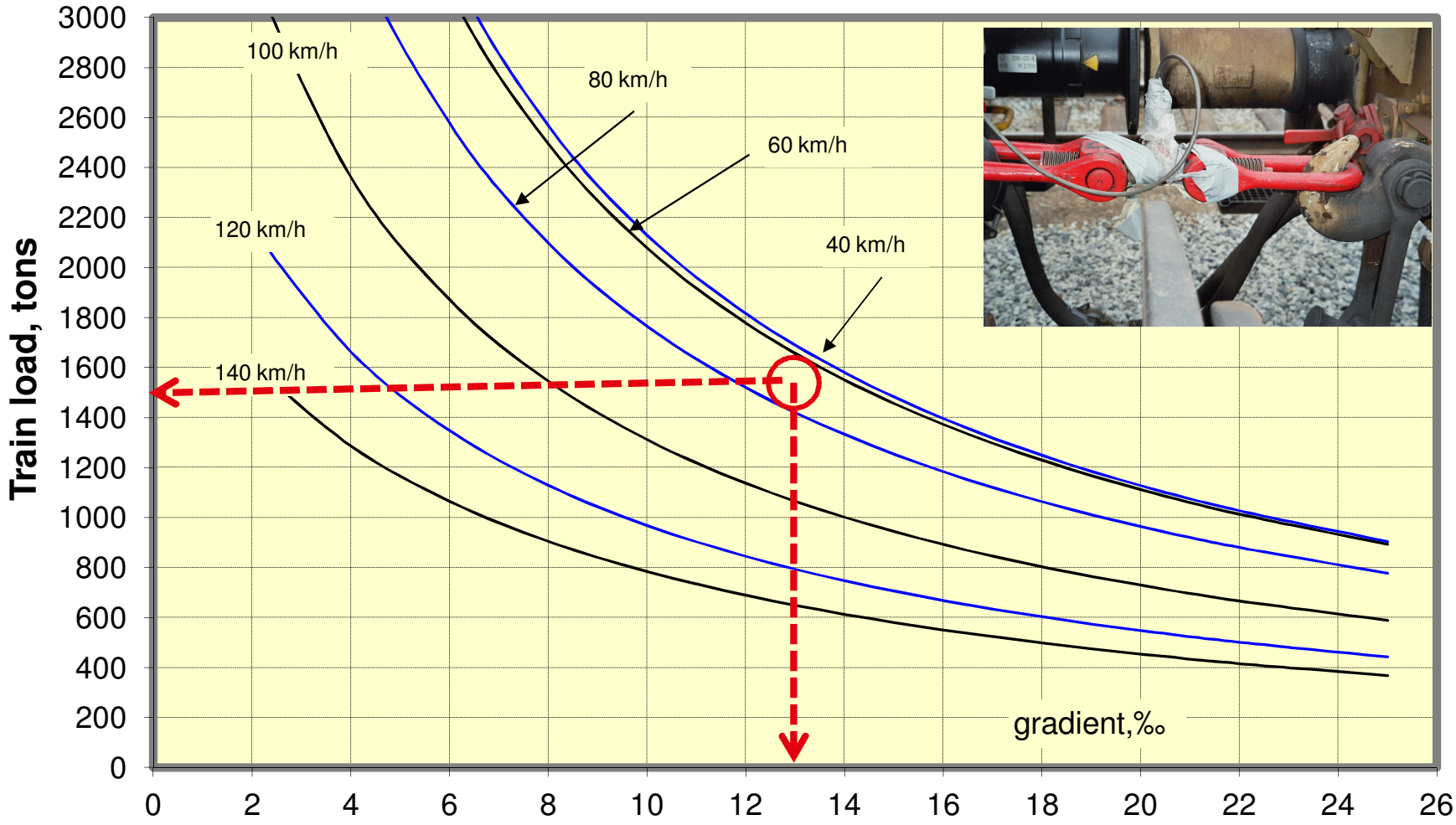
4-axle E-locos can haul 1’400 to 1’600 tons at 80 km/h, also on the 13‰ (1:77) grades up to Beattock Summit



Daventry – Coatbridge Terminal with 13‰ grade up to Beattock Summit

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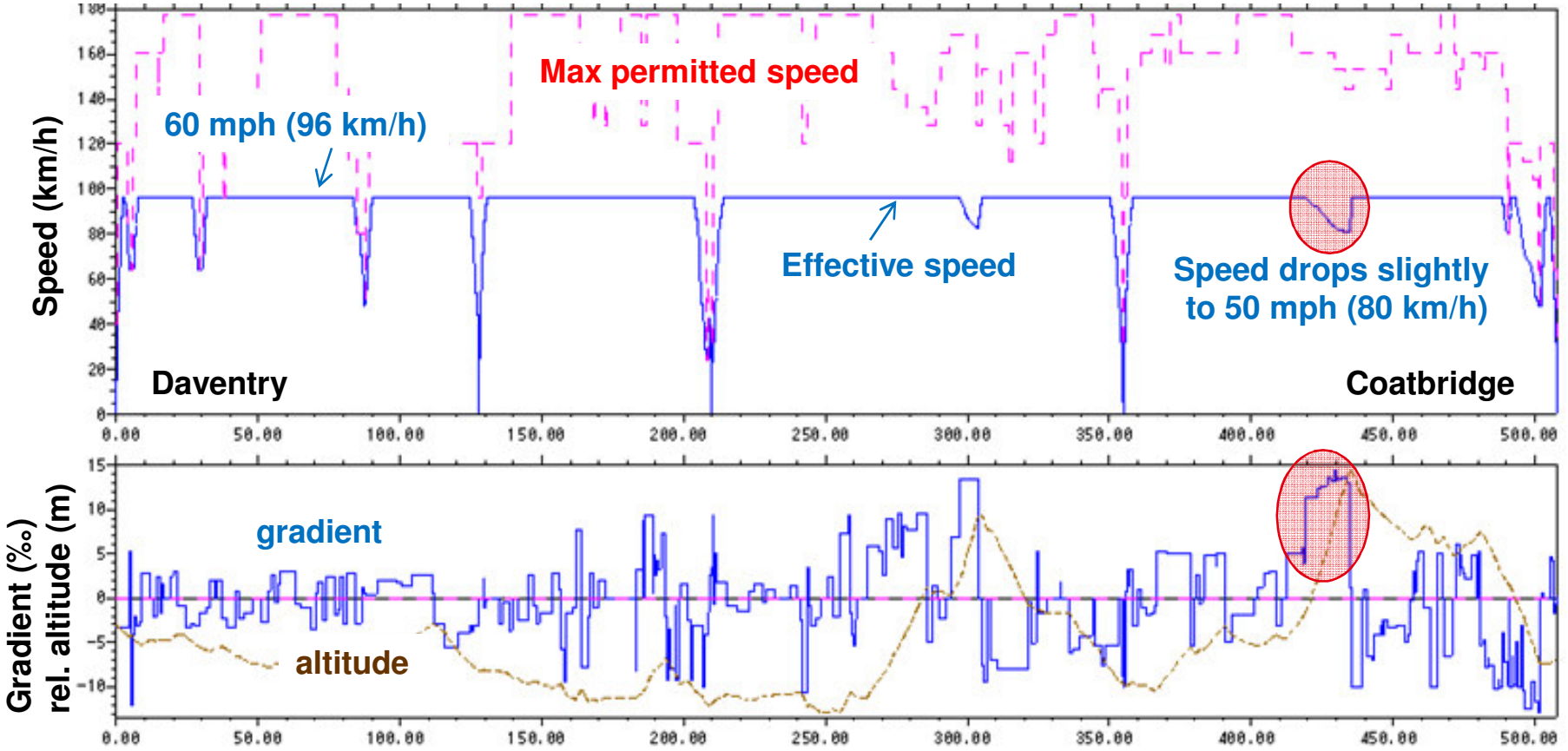
An E-loco + 1’500t can easily run at 60 mph (96 km/h)

Running simulations: Daventry – Coatbridge Terminal at max 60 mph



Actual timetable:

- 2 hours, 8 min.

Traveling time with an electric loco:

- 1 hour, 43 min. at max 60 mph (96 km/h)

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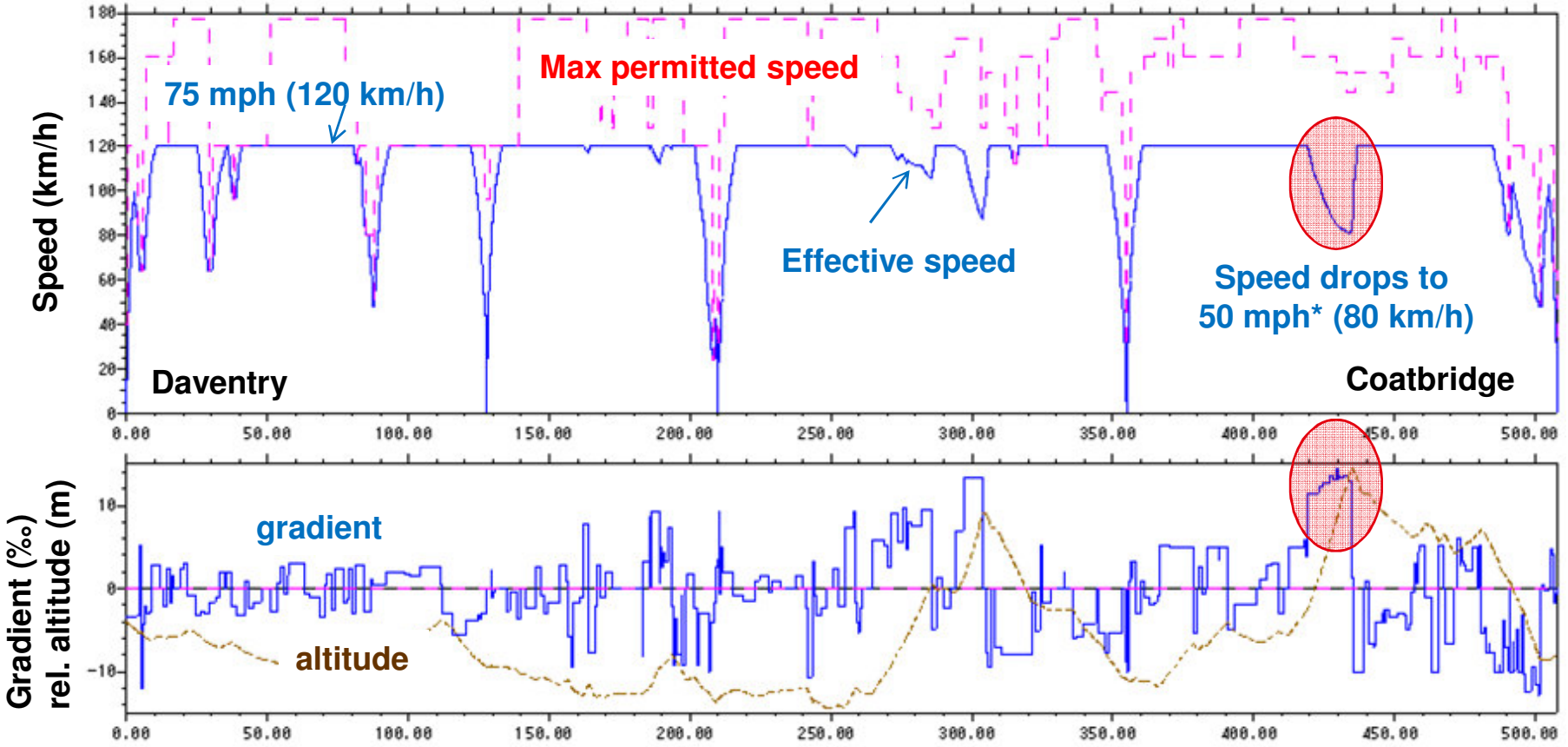
An E-loco + 1’500t can also run at 75 mph (120 km/h)

Running simulations: Daventry – Coatbridge Terminal at max 75 mph



Actual timetable:

- 2 hours, 8 min.

Traveling time with an electric loco:

- 1 hours, 29 min. at max 75 mph (120 km/h)

***) loss of approx. 2.5 min.**

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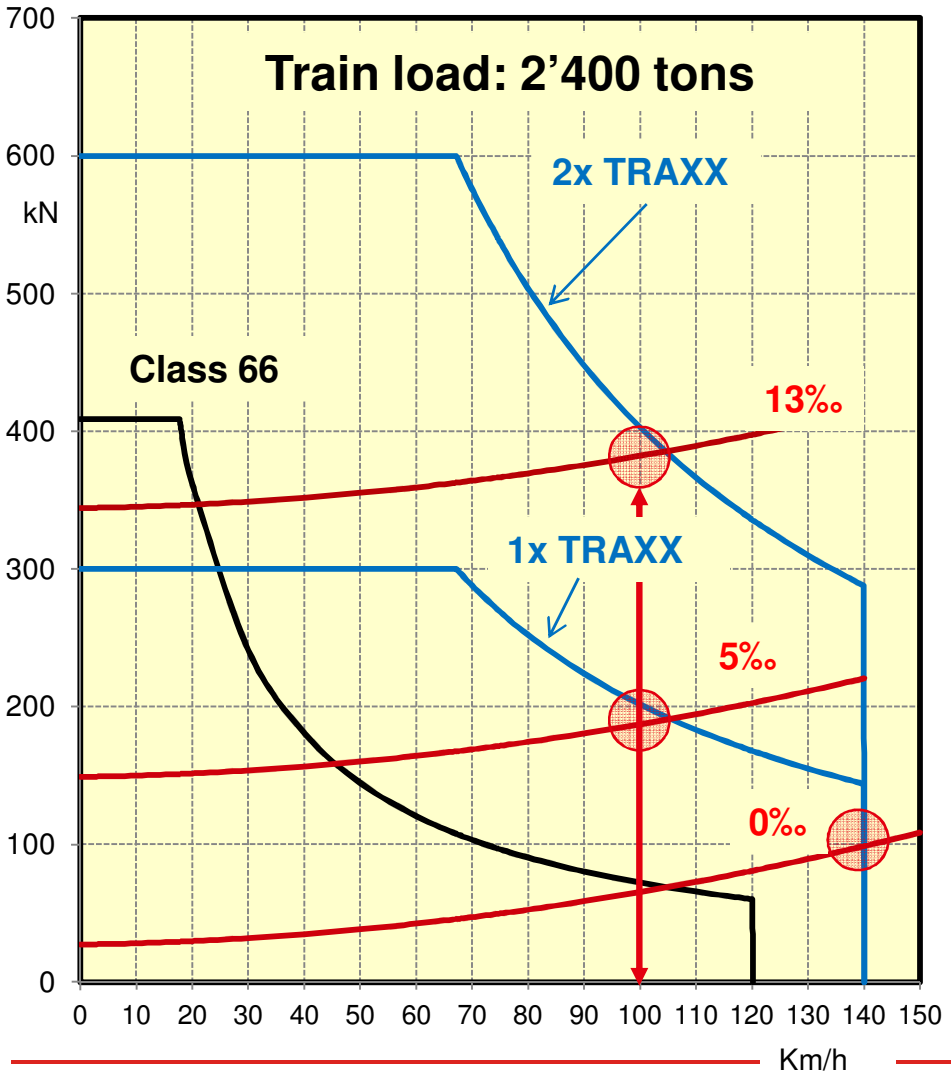
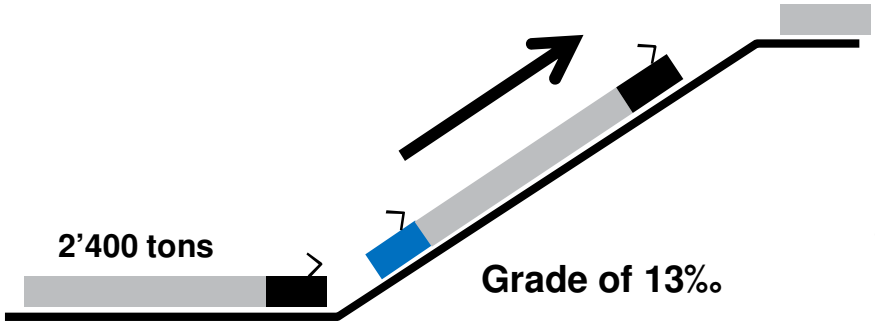
Operation can be overall at 100 km/h with 2’400 tons load

… with an additional pushing loco for the section up to Beattock Summit





Grades of up to approx. 7‰

- A single loco can haul 2’400 tons at 100 km/h on 5‰ continuously (and up to approx.7‰ dynamically)
- This train can continue at 100 km/h up to Beattock summit on 13‰ with an additional pushing loco
- The above procedure is standard practice in Switzerland on the Gotthard line between Erstfeld and Göschenen (26‰, 300 m curves)

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Contents

An electric locomotive for the UK can be derived from the European TRAXX Locomotive Platform → TRAXX UK

TRAXX UK, Performance	
Track gauge	1435 mm
Wheelset arrangement	Bo'Bo'
Max. speed	140 / 200 km/h
Catenary voltage	25 kV AC
Power at the wheel	5'600 kW
Starting tractive effort	300 kN
Braking effort	240 kN
Last Mile diesel engine	Yes
Power Last Mile (at the wheel)	approx. 180 kW
Starting tractive effort, Last Mile	approx. 300 kN
Service weight	~81 tons
Train heating	850 VAC, ~500 kW, 50 Hz
Length over buffers	18'900 mm
Bogie wheelbase	2'650 mm
Wheel diameter (new/worn)	1'100 / 1'010 mm
Drive system	Fully suspended
ATP systems	**UK:** AWS, TPWS; **France:** TVM, KVB, RPS
Standards	TSI, EN, UIC, IEC
Radio remote control, shunting	Yes

Key Features

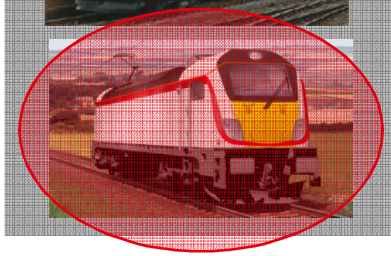
- Meets the UK loading gauges
- Designed for freight and passenger
- Low track and P2 forces with fully suspended drive and short axle base
- Full power regeneration of braking power → 10% average energy savings
- Integrated Last Mile functionality for operation into non-electrified terminals
- Loco available in **two versions**:
  - Operation in UK only
  - Operation UK - Eurotunnel - France

The TRAXX UK is a member of the TRAXX Platform

… with adaptations to meet the UK requirements

TRAXX AC

15 and 25 kVAC



TRAXX DC

3 kVDC

Italy, Spain, Poland

North – South Corridors

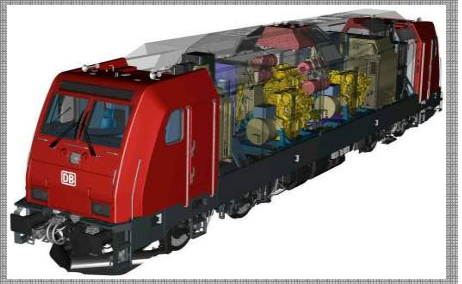
TRAXX MS

15/25 kVAC & 1.5/3 kVDC

Benelux, Italy, Ploand

TRAXX DE

diesel-electric



Non-electrified lines

> 1550 sold TRAXX locomotives

> 1450 TRAXX locomotives in operation

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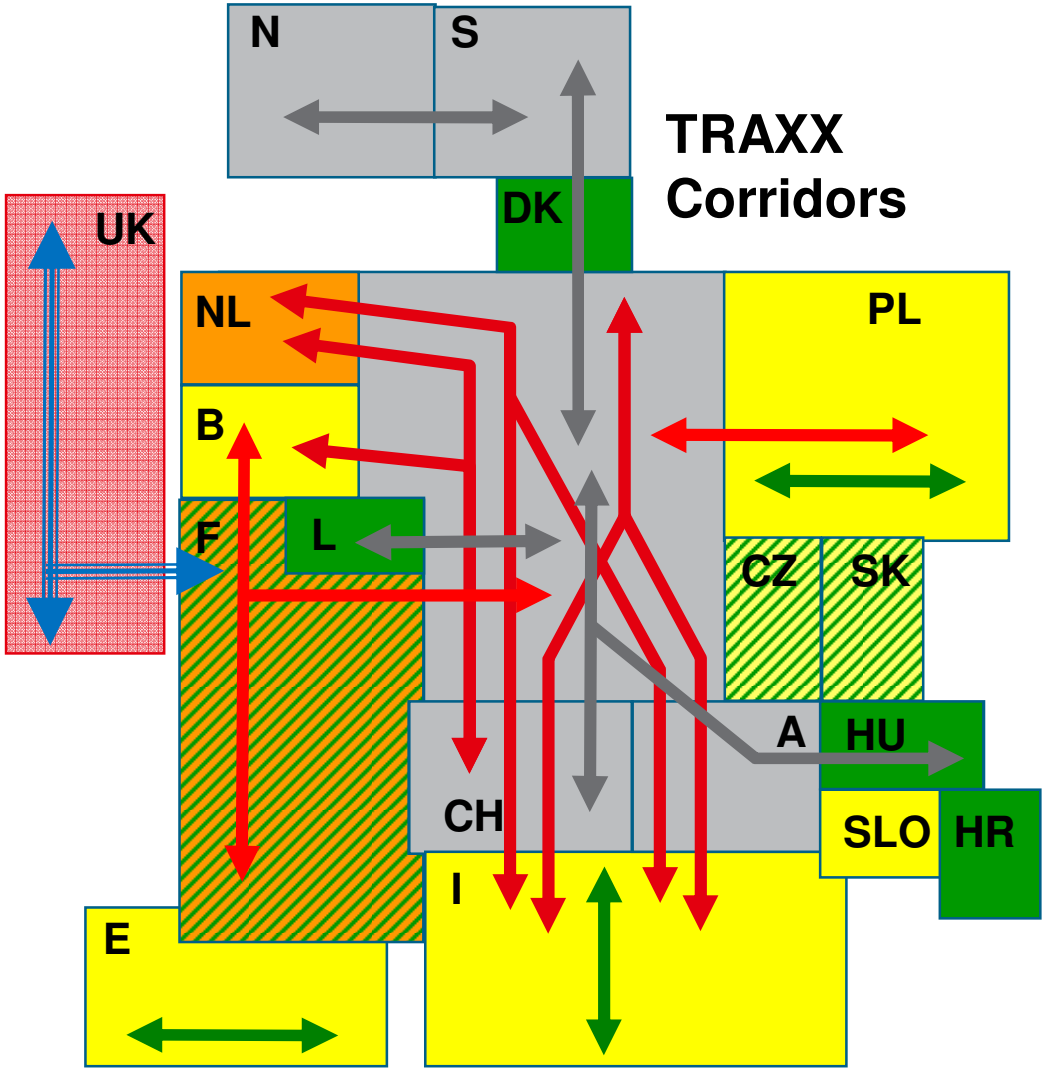
The TRAXX UK is the missing link within the TRAXX Platform for the UK and cross-border services to France



TRAXX Corridors

TRAXX locomotives cover …

- Different corridors
- Different safety systems
- Different applications, heavy freight and high speed passenger services

Electric locomotive types:

- TRAXX AC
- TRAXX MS
- TRAXX DC
- *TRAXX UK*

Catenary systems:

- 15 kV AC
- 3 kV DC
- 25 kV AC
- 1.5 kV DC

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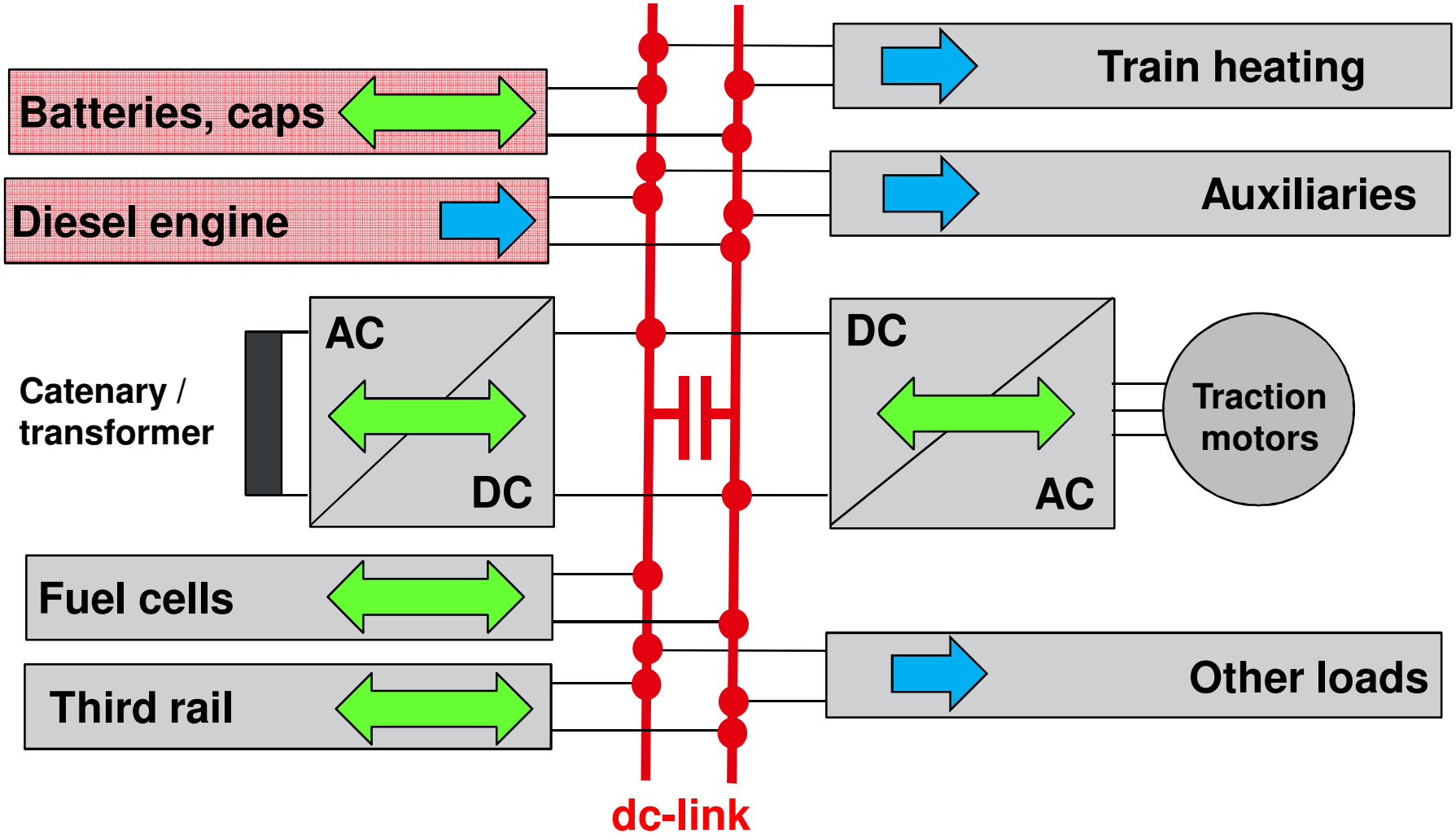
The dc-link of the traction converter is the common interface for adding power sources and loads



Energy flow bi-directional

Energy flow uni-directional

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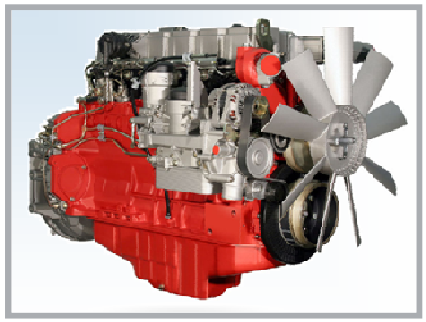
The TRAXX UK is available with a small diesel engine + battery allowing Last Mile operation w/o a shunting loco

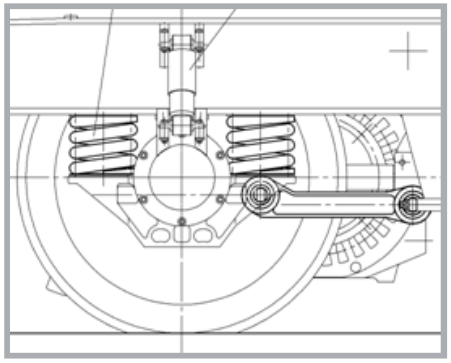
Electric operation
Full power of 5.6 MW at the wheels.
Max speed 140 for freight, 160 km/h for passenger services

Diesel for Last Mile



- Standard industrial engine
- Stage IIIB exhaust emissions
- Intelligent power control

Traction converter



Drive system

Energy storage
Battery boost

Energy flow

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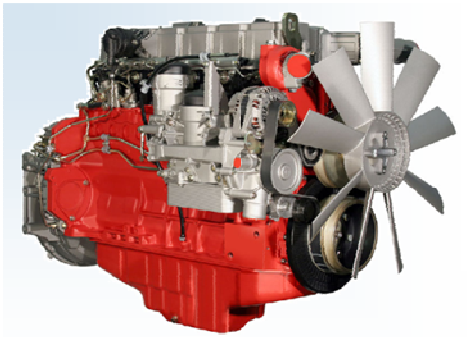
The Last Mile feature is an add-on to TRAXX locomotives

… for seamless operation into short branch lines, sidings and terminals

Last Mile Feature:

- Full 300 kN tractive effort under catenary and with Last Mile
- Diesel engine with Stage IIIB exhaust emissions standards
- Robust industrial diesel engine adapted to the needs of railway applications → low life-cycle costs
- Non-stop transition between electric and Last Mile operation

→ The Last Mile feature opens the door to new logistic concepts in rail freight distribution



Deutz; BR 2013 4V

Industrial diesel engine used for Last Mile

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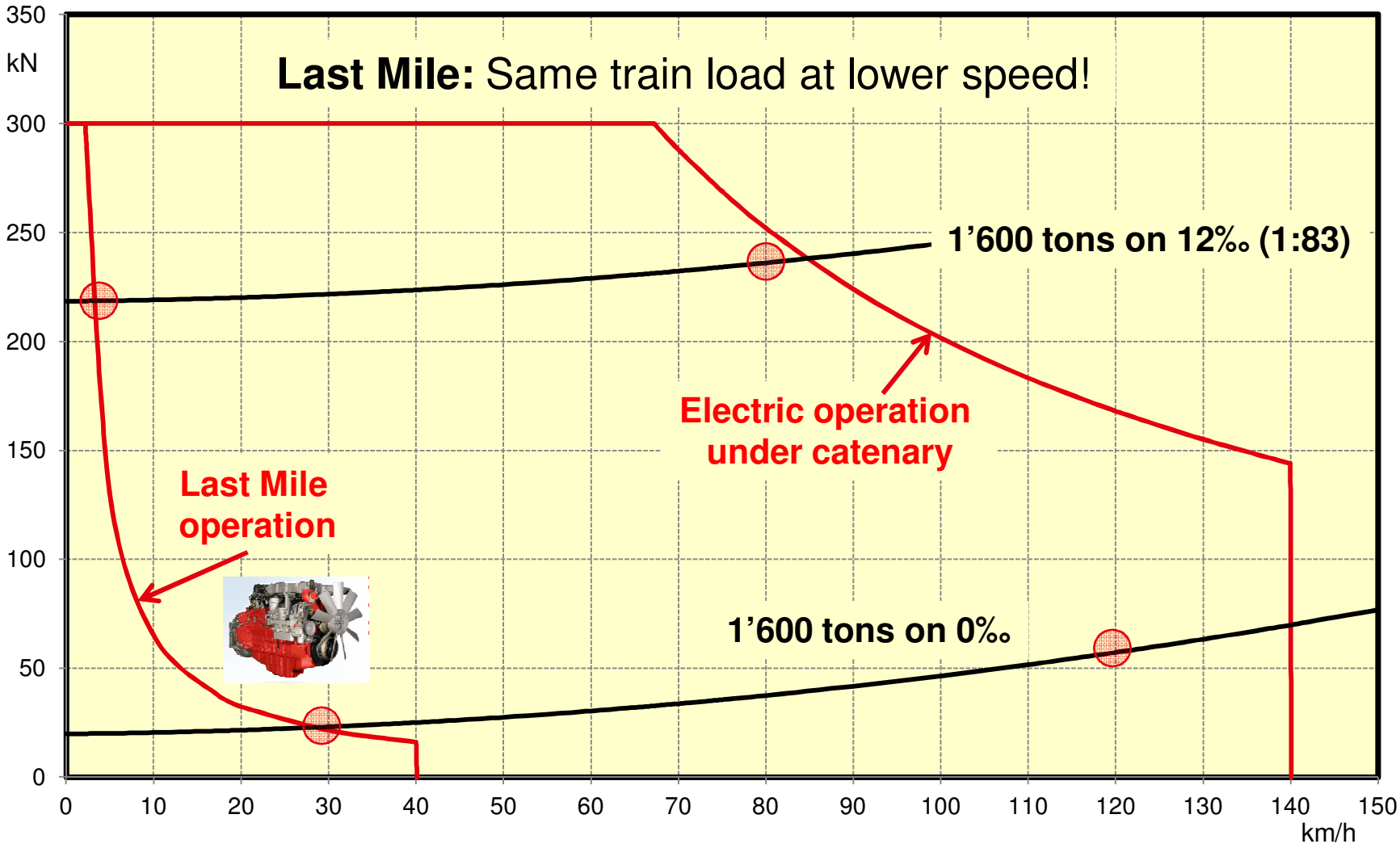
The Last Mile functionality provides the same tractive effort as under catenary → seamless operation



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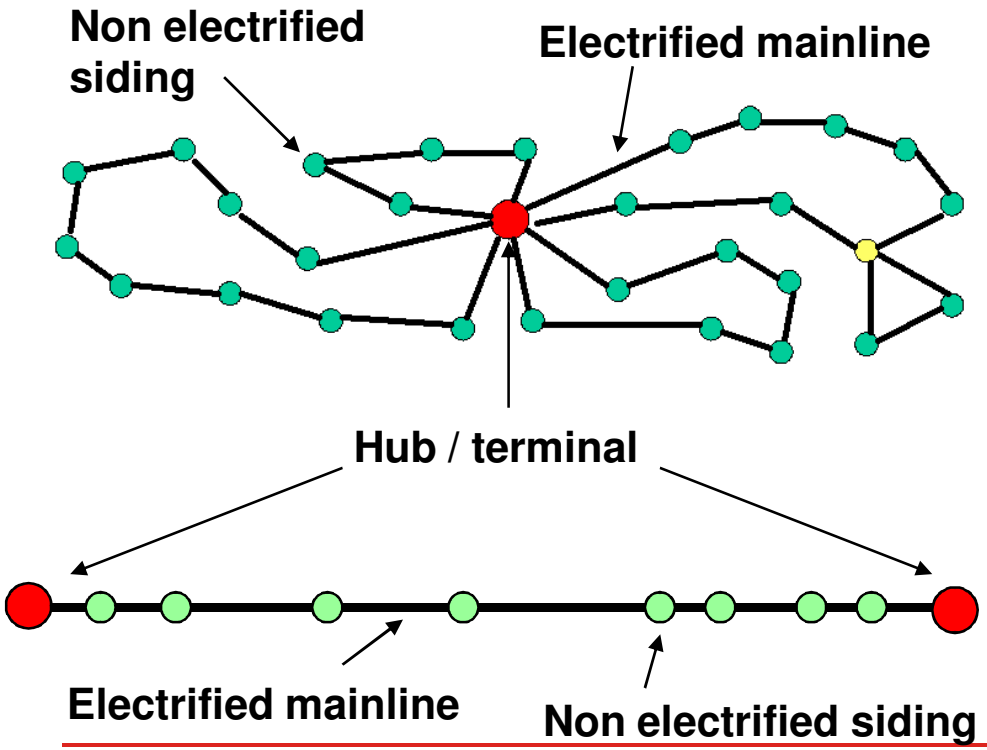
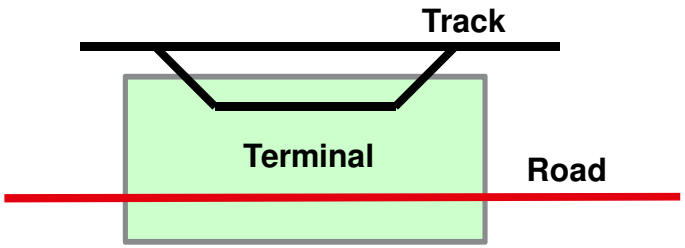
The Last Mile feature allows to serve destinations without the need of shunting locomotives → new logistic concepts

The electric loco with Last Mile can distribute freight along mainlines …

- addressing small terminals w/o shunting locos
- with high acceleration for stop-and-go traffic





Non electrified siding

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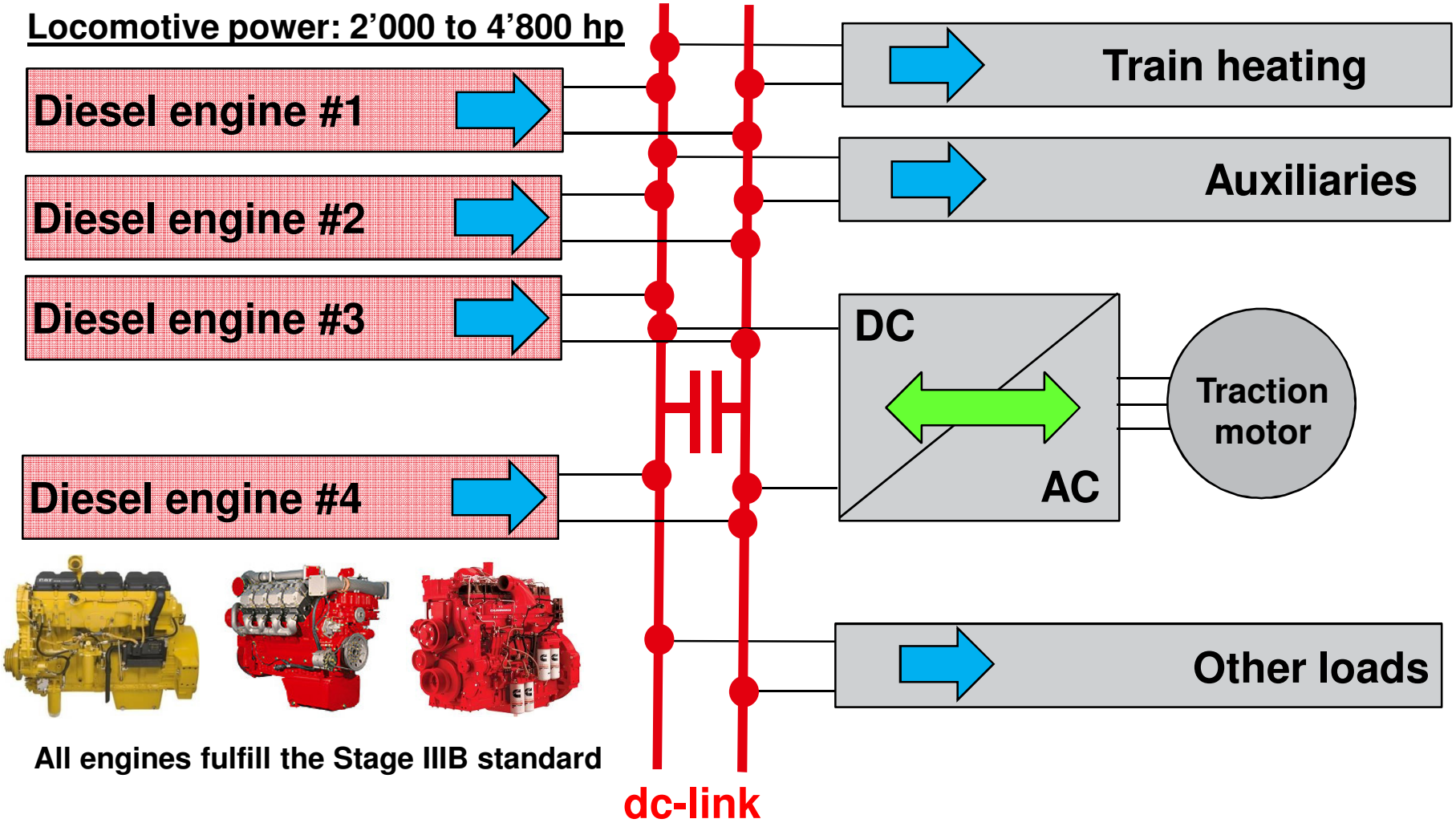
Low cost, robust industrial diesel engines can replace single engines → substantial reduction of life-cycle costs



All engines fulfill the Stage IIIB standard

Energy flow bi-directional

Energy flow uni-directional

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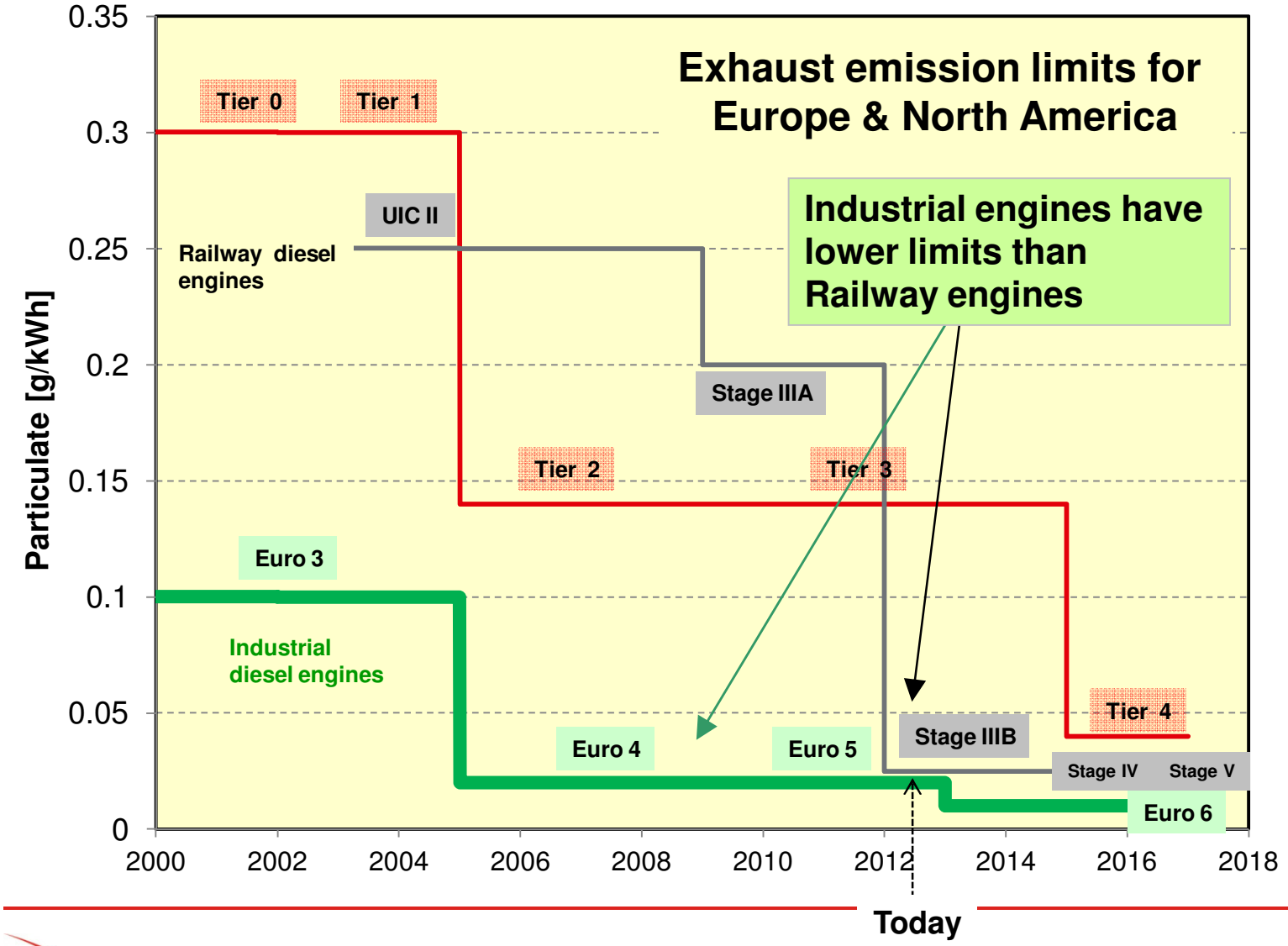
Industrial engines fulfill Stage IIIB exhaust emissions much more easily than large engines – at low fuel consumption



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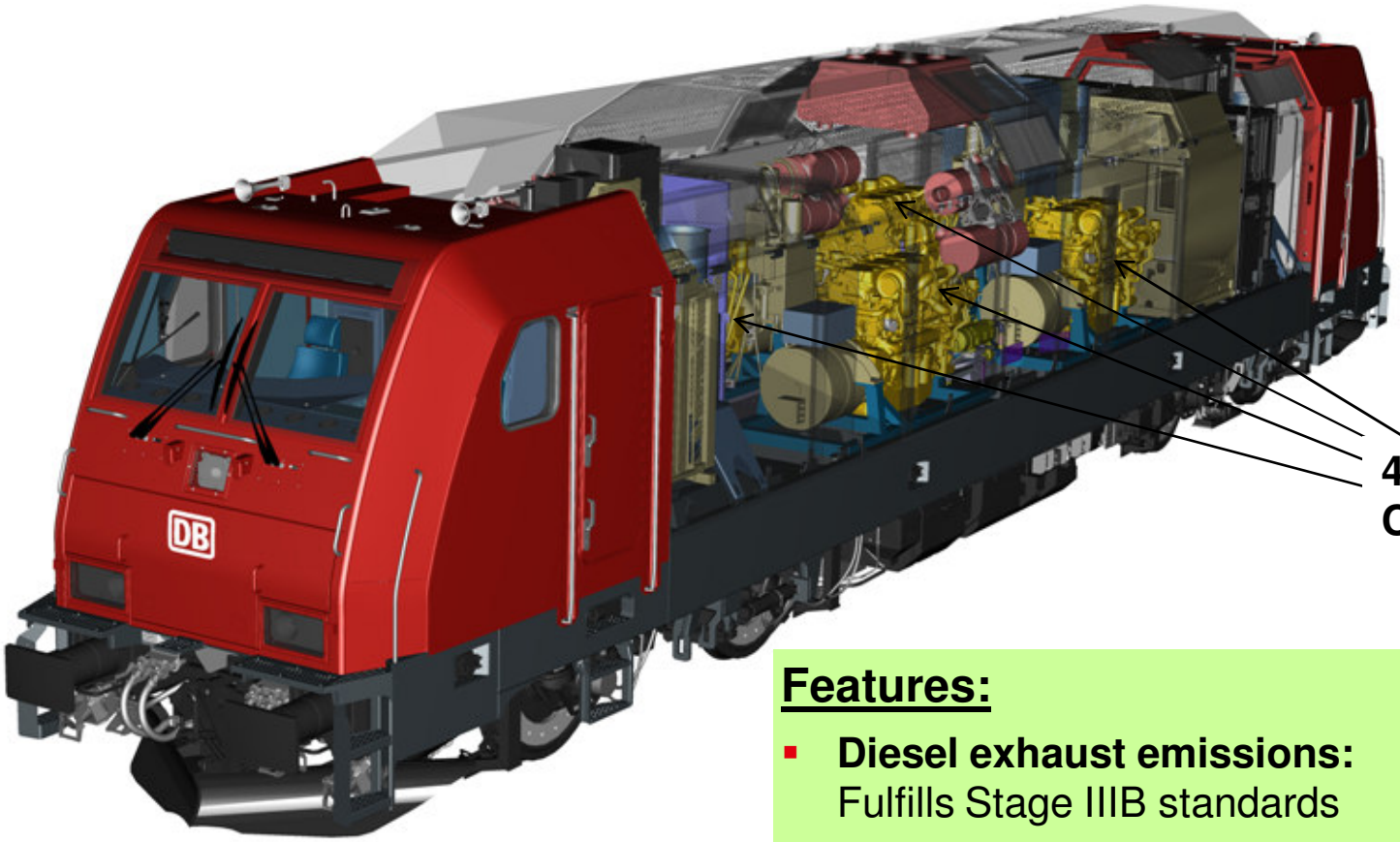
The BR 245 of the German Railways has four high speed engines, with low exhaust emissions → Stage IIIB



Features:

- **Diesel exhaust emissions:** Fulfills Stage IIIB standards
- **Engine control:** Fuel savings with automatic start/stop functionality
- **Applications:** passenger and freight services

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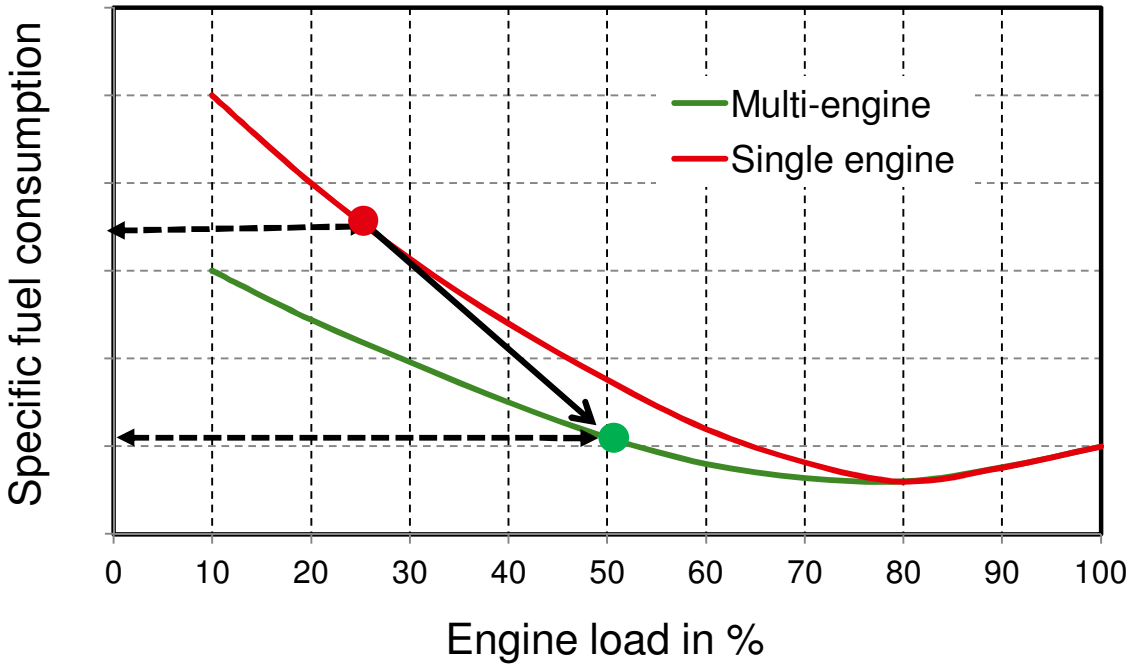
The BR 245: The 5% reduction in fuel consumption leads to cost savings of 1M€/loco per locomotive over 20 years!



In 20 years calculated as NPV:

- **Savings of 1 M€ fuel costs (1'100 tons CO_2)**
  - **150'000 km/year**
  - **Comparison of TRAXX with single engine (MTU 16V4000) and 4x C18**
  - **Fuel cost of 1,23 € / Liter with an assumed escalation of 3% per year**

Fuel savings

- Selective engine control, start-stop feature → 5%
- Inherent higher efficiency compared to large & legacy medium speed engines → 5 to 10%

Other savings

- Up to 50% lower service and maintenance costs
- No obsolescence due to very large engine market
- High availability: Diesel engine is a replaceable module

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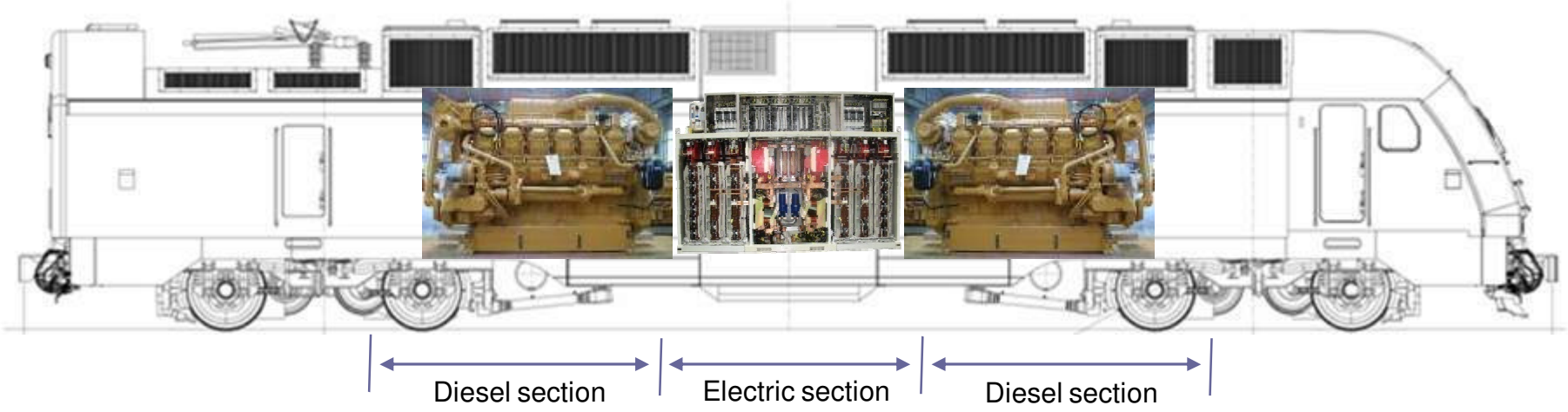
Dual-powered locos for full electric and diesel traction

The ALP-45DP as an example, however with a high axle load of 32 tons



Dual-powered loco for North America

- BoBo configuration
- 32 tons axle load
- 4 MW electric power at the wheels
- 2x 2100 hp (3100kW) diesel engine power

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Is a dual-powered locomotive feasible for the UK?

There are severe limitations due to limited axle load and loading gauge

The 4-axle DP locomotive

- There is a choice of either …
  a) Approx. 3.5 MW electric power + ~700 kW diesel power at the wheels (1 MW diesel engine), or
  b) 5.6 MW electric power + 200 kW Last Mile power at the wheels (230 kW engine + battery)
- 5.6 MW at the wheels is needed in mixed mainline traffic
  → **b) solution of TRAXX UK**
- Future development in next 20 years: To increase the Last Mile power to ≥500 kW with new batteries, fuel cells, etc.

The 6-axle DP locomotive

- It is questionable to fit 5.6 MW electric power and a minimum of 2'000 kW (2'600 hp) diesel engine power into one locomotive …
  – technically, and
  – at a reasonable price, LCC.
- Also, it is questionable from point of view of energy consumption to carry the additional weight of a heavy diesel engine under long stretches of catenary operation.
- Conclusion: The electrification of missing links for freight may be the better solution

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Summary, #1

- **There is a large overlap of electrification with traffic forecasts, however, there are important missing links of electrification to increase the potential of freight services with electric locomotives**
- **Electric locomotives have compared to diesel locos…**
  - a much higher traction power, and
  - a much higher tractive effort above 30 km/h

  and are therefore suited for mixed freight and high speed passenger traffic …
  - with faster train acceleration, lower energy costs, and
  - higher speed of operation at 80 to 120 km/h
- **Examples: On the West Coast Mainline (over the Beattock Summit) a single electric loco can haul …**
  - 1’400 to 1’600 tons at up to 120 km/h (dropping over a short distance to 80 km/h)
  - up to 2’400 tons at 100 km/h with an additional pushing loco used only on the section of higher gradient up to Beattock Summit

Summary, #2

- **The TRAXX UK is an electric loco available in two versions:**
  - For UK only on 25 kV AC for freight and passenger services, max. 200 km/h
  - For UK-Channel Tunnel-Northern France for freight services
- **The TRAXX UK is available with Last Mile …**
  - for operation without catenary into terminals, sidings and short branch lines* without the need of a shunting loco.
  - for new logistic concepts of freight distribution.
- **Modern locos have a traction converter with a dc-link which is the common interface for electric, diesel and energy storage devices**
  - This allows to combine electric traction with diesel engines and batteries (energy storage devices) → Example: The Last Mile of the TRAXX UK consists of small diesel engine + battery boost.
  - In the future we expect further developments with new batteries, fuel cells etc, which increase the capability of Last Mile and lead to further energy savings.

*) The section Felixstowe - Ipswich with Last Mile is hardly realistic due to long travelling time of >1h

Summary, #3

- **State-of-the-art locomotive design permits to use small robust industrial diesel engines fulfilling Stage IIIB exhaust emission standards. The benefits are …**
  - Lower fuel consumption of 5 to 15% compared single and legacy engines
  - Lower maintenance; no obsolescence due to large market of engine spares
- **Future dual-powered locomotives for the UK?**
  - The requirement of full electric power (5.6 MW) under catenary and the limitations of axle load and loading gauge leads to following result:

    4-axle locomotive: The best choice is a high power electric locomotive (5.6 MW at the wheel) with a Last Mile capability for short distance operation without catenary.

    This loco can be used both for freight and passenger services (200 km/h) for increased economies of scale and max. versatility. In addition it has overall low P2 forces (low track access costs). → **This is the objective of the TRAXX UK.**

    6-axle locomotive: It is questionable if such a locomotive is technically and commercially feasible for the UK. Alternative: electrification of missing links!?

The Power of TRAXX - Thank You!

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