LDX

Next Generation of Romanian Diesel-Electric Locomotives

Version: 21 July 2026

1 Purpose & Scope

Romania once stood among Europe's significant locomotive-producing nations, with a complete industrial ecosystem capable of designing, manufacturing, and exporting diesel-electric platforms. Today, that ecosystem has largely disappeared. Only Softronic remains as an active producer, and even its output is limited to a narrow range of electric locomotives and small-scale modernization programs.

Despite this decline, Romania still possesses a strategic industrial asset: **hundreds of LDE1250 and LDE2100 locomotives**, whose frames, bogies, and structural components remain fundamentally sound. These platforms represent one of the largest untapped modernization bases in Central and Eastern Europe. If leveraged correctly, they could form the foundation for a new generation of competitive, export-ready diesel-electric locomotives.

The central purpose of this study is to **identify the correct modernization direction** for these legacy platforms. Past attempts at remotorization or partial upgrades failed because they were driven by technical enthusiasm rather than market reality. To avoid repeating these mistakes, this document begins with a comprehensive exploration of European, Romanian, and global freight trends, operator purchasing behavior, regulatory pressures, and emerging traction technologies.

The scope of this study is therefore threefold:

- **Understand the real market demand** for diesel-electric, hybrid, and dual-mode locomotives in Romania, the EU, and key export regions.
- **Derive the technical and commercial requirements** that a modernized Romanian locomotive must meet to be viable in today's competitive landscape.
- **Define a coherent modernization direction** — a platform architecture, power class, traction philosophy, and hybridization level — that can transform Romania's existing locomotive inventory into a commercially successful product family.

This document does not present a finished product. Instead, it captures the **exploration journey** required to determine what such a product must be. The conclusions that emerge from this journey form the basis for a modernization concept capable of restoring Romania's presence in the locomotive market — not through nostalgia, but through a specification aligned with real operator needs, realistic economics, and global demand.

2 Context

Environmental regulations force Stage V diesel engine emissions in EU.

Rising fuel prices require minimum fuel consumptions.

Aging and retiring workforce makes maintenance more challenging.

Heavy cargo is transported on electrified main lines.

Light hybridization and dual mode locomotives are a new trend.

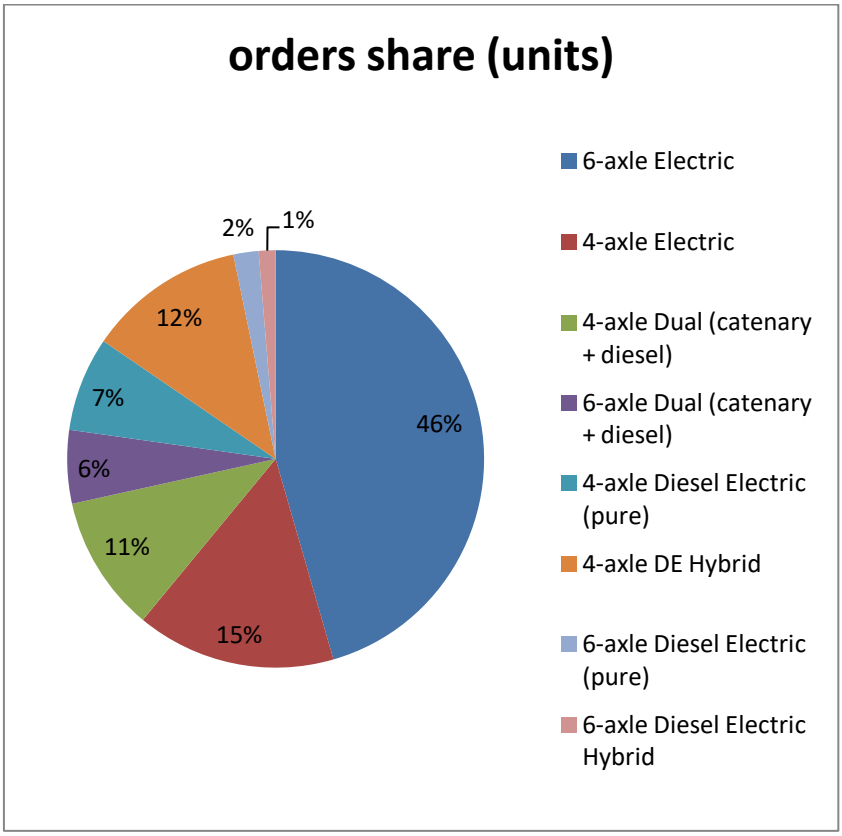
2.1 EU Market Trends

2.1.1 Locomotive Orders by Category – Europe 2025–March 2026

The data is an **estimate** based on confirmed orders and average prices in 2025–2026 (Vossloh, Siemens, CZ LOKO, Alstom, etc.).

Locomotive Orders 2025 – March 2026 (Europe)

Category	Units ordered/ delivered	Main models / buyers	Approx. Price per loco (€)	Notes	typical nr	typical price [ME]	Value [ME]	share (units)	share value
6-axle Electric	~280	Siemens Vectron, Alstom Traxx MS3	5.5 – 7.0 mil.	Largest category	280	6.2	1736	46%	49%
4-axle Electric	~95	Siemens Vectron (4-axle versions)	4.5 – 5.5 mil.	Smaller volume	95	5	475	15%	13%
4-axle Dual (catenary + diesel)	~65	Siemens Vectron Dual Mode (Akiem + others)	5.8 – 6.5 mil.	Fast-growing segment	65	6.1	396.5	11%	11%
6-axle Dual (catenary + diesel)	~35	Siemens Vectron Dual Mode	6.5 – 7.5 mil.	Smaller than 4-axle dual	35	7	245	6%	7%
4-axle Diesel Electric (pure)	~45	Vossloh DE18 pure, CZ LOKO EffiShunter 1000	3.8 – 4.5 mil.	Steady but smaller	45	4.1	184.5	7%	5%
4-axle DE Hybrid	**75**	Vossloh DE18 SmartHybrid (Nexrail 20 + prior)	**4.8 – 5.2 mil.**	Largest in diesel-electric segment	75	5	375	12%	11%
6-axle Diesel Electric (pure)	~12	Various older platforms	4.5 – 5.5 mil.	Very small	12	5	60	2%	2%
6-axle Diesel Electric Hybrid	~8	Rare / special orders	5.5 – 6.5 mil.	Almost non-existent	8	6	48	1%	1%
Total					**615**		**3520**	100%	100%



2.1.2 Locomotive Orders shunter / secondary line - Europe 2025–2026

Vossloh is producing Smart Hybrid locomotive: DE18 Bo-Bo with 1800KW diesel engine, a 105 kWh battery offering 300 kW of power. Recent orders are coming from Nexrail: Leasing Company Nexrail has ordered 20 Vossloh Rolling Stock DE18 SmartHybrid locomotives with updated specifications, taking its total order to 50 of the type. (https://www.railwaygazette.com/traction-and-rolling-stock/nexrail-orders-de18-smarthybrid-locomotives-with-updated-specification/70236.article)

By Mpns - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=177830332

Maker	Model	Buyer / Leasing	Nr	Power (kW)	Estimated Price (€)	Type	Notes
Vossloh Rolling Stock	DE18 SmartHybrid	Nexrail	**20**	**1.800**	4.8 – 5.2 mil.	**Hybrid**	Biggest order (battery 106 kWh) Other 30 already ordered
Vossloh Rolling Stock	DE18	Northrail (Sweeden/Norway)	**10**	**1.800**	4.0 – 4.4 mil.	Pure diesel	+ 10 option
Vossloh Rolling Stock	DE18 Stage V	SPITZKE SE	**10**	**1.800**	4.1 – 4.5 mil.	Pure diesel Stage V	Deliveries ongoing
CZ LOKO	EffiShunter 1000	Elektrizace železnic Praha	**7**	**895**	3.2 – 3.6 mil.	Pure diesel	For electrification works
CZ LOKO	EffiShunter 1000	CZ/SK Firms	~8–10	**895**	3.2 – 3.6 mil.	Pure diesel	Small constant orders
Siemens Mobility	Vectron Dual Mode	Akiem	**10** (+40 option)	**2.000+**	6.0 – 6.5 mil.	**Dual-mode (hybrid)**	Mainline + shunting (4 axle)

Key observations:

- Electric locomotives (especially 6-axle) still dominate the overall EU market by value.
- Dual-mode (catenary + diesel) is the fastest-growing segment.
- Diesel locomotives segment is split between Dual Mode and Hybrid solution
- Pure diesel-electric (both 4- and 6-axle) is shrinking
- In diesel-electric world, High power 4 axle locomotives sell better: they do 6 axle job at 4 axle cost
- Even light hybridization boosts sales as offers both: lower operating costs and green credentials
- Light hybrids are still successfully competing with Dual Mode locomotives, being less capital intensive.

2.1.3 Future of EU Rail

Long term solution is EB Dual Mode locomotives (electric + battery): catenary line is the main source of energy. Instead of full electrification of (secondary) lines, power isles are created with gaps of ~50 km. The gaps are covered by battery power and then batteries recharge during a segment of electrified line that will be followed by another gap. Batteries are more cost effective than transition to hydrogen.

Short/medium term solution is ED Dual Mode locomotives (electric + diesel): transition electric-non-electric lines do not require locomotive change reducing operation time and costs. Diesel offer a backup in case of power shortages on electric lines due to maintenance, modernization works or malfunctions.

2.1.4 Conclusions for EU

- **4 axle light hybrids with powerful diesel engines** are occupying a large share of new Diesel-Electric locomotives segment in Europe; they are a happy case when green tech reduces operation costs;
- Advantages that explains their relative success:
    - reduced maintenance costs with the main engine through less wear/less running hours (battery removes idle, low speed operation purely electric)
    - reduced running costs through fuel savings by:
        - regenerative braking
        - reduced idle
    - 6 axle power (reference LDE 2100) at 4 axle costs
    - more affordable and less complex that dual mode locomotives
    - versatile: from shunting to light/medium freight
    - green credentials: reduced emissions/limited silent operation/limited zero emissions operation

2.2 RO Market Trends

The Romanian locomotive market is undergoing partial modernization driven by EU funds (PNRR and Modernization Fund), and very old fleet renewal with less old and more powerful used diesel locomotives.

2.2.1 Key Recent Developments (2024–2026)

Event	Details	Impact
GFR acquires 25 Class 66 locomotives	Second-hand from DB Cargo UK. Deliveries ongoing 2026–2028.	GFR is aggressively replacing ageing LDE2100 and LDH fleets with used but newer and more powerful 6 axle locomotives.
PNRR – Electric locomotive modernization	Softronic and Reloc are modernizing 55 electric locomotives for CFR Călători. ~24 units already delivered.	Significant upgrade of the passenger fleet.
PNRR - Diesel-hydraulic to battery conversion	20 LDH locomotives are being converted to battery-electric under PNRR.	First real steps toward zero-emission shunting.
New electric locomotives	First Alstom Traxx 3 MS units delivered to ARF.	Expansion of the modern electric fleet.
Local rebuild activity	Softronic continue steady delivery of modernized electric locomotives. Reloc converts LDHs to Battery only shunters.	Local industry remains active in the rebuild segment-but no diesel rebuild.

2.2.2 Market Insights

- **Private operators buy cheap power: Freight (GFR / Grampet Group dominant)**: Acquisition of high-power (3300 HP) 6-axle locomotives. Preference for cost-effective solutions rather than brand-new Western locomotives.
    - https://clubferoviar.ro/gfr-locomotive-diesel-second-hand/

> Railway Gazette International precizează că GFR este vârful de lance al Grupului Grampet, care deține aproximativ 380 de locomotive, 16.500 de vagoane și operațiuni în România, Germania, Bulgaria, Ungaria, Croația, Moldova, Serbia, Grecia, Slovenia și Macedonia de Nord. Citat de jurnaliștii britanici, președintele GFR, Sorin Chinde, a declarat că achiziționarea locomotivelor Clasa 66 „se aliniază cu strategia Grupului Grampet de a investi în material rulant de înaltă performanță, care ne sporește eficiența operațională", iar acestea vor deveni „coloana vertebrală" a parcului său de locomotive diesel. "Înlocuirea parcului actual de locomotive LDE 2100, utilizat pentru tracțiune diesel, a fost necesară din cauza creșterii costurilor de întreținere a parcului existent, cauzate de vechimea acestora și de dificultatea tot mai mare de a găsi piese de schimb. Caracteristicile superioare de putere și disponibilitatea ridicată a locomotivelor Clasa 66 ne vor permite să retragem din serviciu un număr mai mare de locomotive de 2.100 CP decât numărul de unități achiziționate de la DB Cargo UK", a spus el.

- **PNRR is used for zero emissions locomotives**:
    - modernization of Electric Locomotives
    - **Shunting / Industrial**: battery conversions with PNRR.
- **Passenger (CFR Călători)**: Focus on electric locomotives and new EMUs. Diesel fleet renewal is ... zero.

2.2.3 Purchase Decision Factors

Factor	Insights	Observed behavior
Affordable	Private operators refuse to pay Western prices (4.8–6.5 mil. €).	GFR / Grampet bought 25 second-hand Class 66 (4-axle) from UK because they were far cheaper than new DE18. Class 66 typically sell in the 1.4 – 2.2 million € per unit range (as-is or lightly refurbished).
Reliable	Old Sulzer 6LDA28 and EMD 710 engines have high maintenance costs and frequent breakdowns.	Operators openly complain about downtime of LDE2100 and LDE1250 fleets. They want more uptime.
Stage V engines	It is not clear if stage V is mandatory for heavy rebuilds in RO	No recent re-motorization
Modern AC traction	Compared to DC: better power, control and reliability	Electric Locomotives modernizations from Softronic switch to AC
DC traction	DC motors from the 1970s–80s are still found on powerful locomotives from used market	GFR's Class 66 purchases use DC motors.

2.2.4 Conclusions for Romania

Private operators are in search of reliable and powerful diesel locomotives.

One powerful locomotive could replace 1.5..2 old locomotives, reducing the fleet size and operations and maintenance costs.

2.3 Romanian Infrastructure

2.3.1 Electrification

Only 40%+ of the 10 000 km of Romanian railways are electrified.

This is reflecting in the recent acquisitions of used 3300 HP Diesel-Electric locomotives (Class 66) from UK.

Romania remains tributary to diesel traction:

https://clubferoviar.ro/gfr-locomotive-diesel-second-hand/#:~:text=Dup%C4%83%20achizi%C8%9Bia%20de%20automotoare%20IC4%20de%20la,de%20marf%C4%83%20din%20Rom%C3%A2nia%2C%20Grup%20Feroviar%20Rom%C3%A2n.

România rămâne tributară tracțiunii diesel

Concluzionând, România continuă să cumpere automotoare și locomotive diesel second hand din țările vest europene, chiar dacă la nivelul blocului comunitar se pune accent pe reducerea emisiilor.

Cum țara noastră nu a electrificat aproape deloc din rețea în ultimii 35 de ani, transportul feroviar rămâne tributar tracțiunii diesel. Din cei aproximativ 10.000 km de rețea din România, doar puțin peste 40% sunt electrificați.

2.3.2 Rail gradients

Are published online:

https://cfr.ro/files/ddr/EN%202026/Annex%209.pdf

Typical freight corridors (non-electrified): ruling gradients 1.0–1.6 % on most routes (CFR Network Statement 2026, Annex 9).

The most important route is Constanta-Curtici. The most difficult segment is Predeal-Brasov with gradient 2% and length 26 km.

2.4 Cargo volume in Romania

Full-year 2025 aggregated rail freight tonne-kilometers (t-km) for Romania is not yet publicly released in complete form (as of 29 March 2026).

The National Institute of Statistics (INS) has published only partial data so far:

First 9 months of 2025 (Jan–Sep): Total goods transported by rail = 30.11 million tons (–8.4 % vs. the same period in 2024). Domestic transport = 79.3 % of the total.

January 2025 only (private operators, who handle the majority of non-electrified diesel freight): 1.28 billion tonne-kilometers (–30 % vs. January 2024).

Estimations from these data:

2025 Cargo volume / month [mil t/month]	3.35
2026 Cargo volume / month [mil t/month]	2.34
2026 Cargo freight / month [mil t-km/month]	1280
2026 Cargo distance / [km/month]	546

A possible train's usage pattern that would cover those volumes:

trains/day	111
average speed [kph]	20
weight [t]	1200
work time/day [h]	16
distance/day [km]	320
Cargo freight / month [mil t-km/month]	1278.7

So, ~100 (very slow) trains, working 16h / day and pulling medium ~1200 t trains would cover the monthly rail transport.

2.5 Rail Operations Profitability

2.5.1 Romania

Major Romanian Rail Operators – Financial Overview 2023–2024

(all figures in RON million, rounded)

Operator	Ownership / Type	2024 Turnover	2024 Net Result	2023 Turnover	2023 Net Result	EBITDA / Operating Result (2024)	Notes / Market Position
GFR (Grup Feroviar Român)	Private Freight (Grampet Group flagship)	**1,027**	**+2.7**	1,055	+23.8	~135–153 (est. 13–14.5 %)	Largest private freight operator; aggressive fleet renewal (25× Class 66)
Grampet Group (consolidated)	Private (GFR + manufacturing + leasing)	~2,065 (€413 M)	Not public	~2,170	~106	**+285 (€57 M)**	Group level is much stronger; finances big investments
CFR Marfă	State Freight	**677**	**–329**	779	–231	**+6.8** (operating/EBITDA)	Heavy losses, debts > RON 1 bn to state; still in restructuring
CFR Călători	State Passenger	Not disclosed (heavily subsidized)	**+15** (first profit in ~10 years)	—	Heavy loss	Not public	Focus on electric locos + EMUs via PNRR
TIM Rail Cargo	Private Freight	**432**	**+1.6**	486	+0.6	Not public	Smaller private player

Operator	Ownership / Type	2024 Turnover	2024 Net Result	2023 Turnover	2023 Net Result	EBITDA / Operating Result (2024)	Notes / Market Position
DB Cargo Romania	Private (DB Group)	**428**	**–13.1**	483	+12.1	Not public	Part of German DB; also loss-making in 2024

GFR seem to be the only profitable operator. The detailed information about profits by rail corridor is unavailable and confidential. The most likely profitable corridor is Constanta-Curtici (via Predeal - Brasov). It connects the Constanta port to the TEN-T Danube Rhine transport artery. Cargo consists of cereals, petroleum, containers, coal, and cement. The Constanta-Curtici corridor is fully electrified.

Figure 1: Alignment of the RD-Corridor

https://transport.ec.europa.eu/system/files/2020-09/4th_workplan_rhd.pdf

2.5.2 Europe

Segment	Profitability Status (2025 data)	Key Operators & Corridors	Why It Works (or Doesn't)	LDX Fit
Port → Mainland Cargo (intermodal, containers, bulk)	**Highly profitable** (private challengers)	Private freight (non-incumbents): GB Railfreight, Rail Cargo Group challengers, GFR/Grampet, Naviland Cargo, PCC Intermodal, etc. Corridors: North Sea (Rotterdam/Antwerp/Hamburg → hinterland), Atlantic, Orient/East-Med (Constanța → Curtici/Bucharest), Baltic	High volume + backhauls + long distances = best margins. In their 2024–2025 report, UIRR members recorded +5.19 % growth in consignments and +8.41 % growth in tonne-kilometres — confirming that port-hinterland combined transport is one of the few genuinely growing and profitable segments in European rail freight. Port terminals growing despite disruptions. Private operators capture 49 %+ of freight market.	**Perfect** – LDX 1000 (hybrid shunter/light freight) for last-mile/port yards; LDX 3000 (dual-mode) for mainline + non-electrified gaps. 25–35 % fuel savings = direct EBITDA boost.
High-Speed Passenger (open-access)	**Commercially viable on prime corridors**	Italo (Italy), Ouigo (France/Spain), Trenitalia France, FlixTrain, private entrants (Kevin Speed 2025–26)	Dense corridors (Paris–Lyon, Madrid–Barcelona, Rome–Milan) allow high load factors + low-cost models. EU 2025 High-Speed Rail Action Plan pushes competition.	**Limited** – mostly electric. But dual-mode LDX 3000 useful for last-mile or non-electrified extensions.
Incumbent Freight (DB Cargo, SNCF Fret, CFR Marfă)	Loss-making / break-even	State-linked incumbents	High fixed costs + infrastructure charges + competition from private challengers	Low
Regional / PSO Passenger	Heavily subsidized	DB Regio, SNCF TER, UK TOCs, CFR Călători	PSO contracts + public funding required	None (electric focus)

Sources (2025–2026): UIRR Report 2024-25, CER Economic Footprint Study 2025, EU Rail Market Monitoring Report 9 (2025), Bundesnetzagentur Railway Market Analysis 2025, European Commission High-Speed Rail Action Plan (Nov 2025), TEN-T updates.

2.5.3 Mining Rail Profitability Overview (2025–2026)

Region	Profitability Level	Key Operators / Corridors	Main Commodities	Rail Model	2025–2026 Highlights / Risks	LDX Fit?
Australia	**Very High** (world benchmark)	Pilbara (BHP WAIO, Rio Tinto, Fortescue, Roy Hill)	Iron ore (main), coal	Privately owned heavy-haul networks	Massive export earnings (~$114 bn iron ore 2025–26). Autonomous trains (AutoHaul) cut fuel/labor 15 %+	Medium – hybrid savings attractive for non-autonomous segments or yard ops
Latin America	**High** (strong cash generator)	Brazil – Vale Carajás, EFVM, etc.	Iron ore, copper, nickel	Vertically integrated (mine-owned rail)	Vale: 336 Mt iron ore in 2025 (+2.6 % YoY). Strong EBITDA contribution	High – LDX 3000 dual-mode/hybrid perfect for non-electrified sections + port yards
Africa	**Medium / Mixed** (high potential but legacy issues)	South Africa (Transnet/Kumba), Guinea (Simandou), Angola (Lobito Corridor), Mauritania	Iron ore, copper, coal	Mix: state-owned + emerging dedicated corridors	Transnet still loss-making but improving. New projects (Simandou, Lobito) expected highly profitable once built	High for new corridors – hybrid lowers fuel/maintenance in harsh conditions

2.5.4 The Mauritania Iron Ore Train

Zouérat → Nouadhibou is genuinely one of the most fascinating heavy-haul rail routes on Earth.

It's a proper "train of legend" — a 704 km single-track diesel-electric line that crosses the Sahara Desert, carrying some of the world's longest and heaviest freight trains. Many rail enthusiasts call it the ultimate desert iron-ore railway.

Quick Facts (as of April 2026)

Feature	Details
Route	Zouérat (iron mines) ↔ Nouadhibou (Atlantic port)
Length	704 km (437 miles)
Train length	Up to **3 km** (1.9 miles) long
Train composition	2 diesel-electric locomotives + 200–210 ore cars + 2–3 service cars
Load per train	~17,000–18,000 tonnes of iron ore
Annual traffic	~16.6 million tonnes of iron ore
Operator	SNIM (Société Nationale Industrielle et Minière) — state-owned mining company
Gauge	Standard 1,435 mm
Electrification	**None** — 100 % diesel-electric
Conditions	Extreme Sahara heat, sand, dust, very long hauls with almost no intermediate stops

2.5.4.1 Current Situation & Opportunites (2025–2030)

SNIM is in full expansion mode: Iron ore is ~25 % of Mauritania's GDP and ~half of its export earnings. In **November 2025**, the African Development Bank (AfDB) and European Investment Bank (EIB) signed a **$275 million** financing package ($150 M AfDB + $125 M EIB) specifically to modernise this exact corridor. Scope includes:

- Track rehabilitation
- **42 km of new track** to reach two future mines (El Aouj and Atomai)
- New locomotives and wagons

Goal: **double transport capacity by 2030**

SNIM already has plans (from 2024–2025) to buy up to **36 new locomotives** and **1,743 new wagons** as part of a larger $467 million logistics program.

Current fleet: Mostly older EMD (Electro-Motive) diesel-electrics (SDL40-2 and newer SD70ACS) — tough, but high fuel consumption in the extreme heat and dust.

2.5.5 Conclusions

The profitable rail operations are of 3 types:

- High speed passenger between metropoles
- Port to hinterland cargo
- Mining

The rest is subsidized.

3 Typical Performance Envelope

Load Type: T4 (loaded 4-axle freight wagons)

Power [kW]:	740	Power [HP]:	1250	LDE1250
Power [kW]:	1125	Power [HP]:	1900	LDX1900
Power [kW]:	1243	Power [HP]:	2100	LDE2100
Power [kW]:	1440	Power [HP]:	2432	Vossloh DE18
Power [kW]:	1954	Power [HP]:	3300	Class 66 UK

Speed [kph]
Train weight [t]

e [%]	150	300	450	600	750	900	1050	1200	1350	1500	1650	1800	1950	2100	2250	2400	2550	2700	2850	3000	3150	3300	3450	3600	3750	3900	4050	4200	4350	4500	4650	4800	4950	5100	5250
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0.0%	100	100	100	100	100	100	100	100	100	100	100	100	100	97	94	92	89	87	86	84	82	81	79	78	77	75	74	73	72	71	70	69	68	67	66
0.0%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	95	93	91	89	87	86	84	83	81	80	78	77	76	75	74	73	72	71	70	69
0.0%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	96	94	93	91	89	88	86	85	83	82	81	80	79	78	77	76	75	74
0.0%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	97	96	94	93	91	90	89	88	87	86	85	84
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4.0%	100	58	39	29	23	19	16	14	13	11	10	9																							

Table 1

3.1 Power vs. weight vs. slope

Table 1 shows traction envelope (slope vs. weight) for various Diesel Engine powers. The rule of thumb is that power (in HP) is equal to max weight (in t) for 2% slope at 10kph.

So Class 66 can pull up to ~3300 t on a 2% slope.

Vossloh DE18 can pull up to ~2400 t on a 2% slope.

LDE2100 can pull up to ~2100 t on a 2% slope.

LDE1250 can pull up to ~1250 ton a 2% slope.

The train weight limit is also given by adhesion limit and sector gradient.

3.2 Adhesion limit: 4 axle vs. 6 axle

nr of axles	Locomotive weight [t]	u	Ft [kN]	Net Power @ 10 kph [kW]	Diesel Power 10 kph [CP]	max weight at 2% gradient [t]	max weight at 1.2% gradient [t]
4	80	0.33	259	719	1215	1300	2145
6	120	0.33	388	1079	1823	1950	3218

Maximum power at 10 kph before breaking the adhesion limit is ~1250 HP for 4 axles and ~1850 HP for 6 axles. The total train weight limit is ~1300 t for 4-axles and ~1950 t for 6-axles for 2% gradients. Even if powerful, a 4-axle locomotive cannot use that power to pull heavy trains on big gradients (2%) due to adhesion limit. On medium gradients (1.2%) a 4-axle locomotive can pull ~2000 t.

So, for a 4-axle locomotive, the surplus power above minimum required to exploit available adhesion (i.e. ~1250 HP) can translate **not to higher train weight**, but can translate to **higher speeds**.

nr of axles	Locomotive weight [t]	u	Ft [kN]	max weight at 1.2% gradient [t]	target speed [kph]	required net power [kw]	required diesel power [CP]
4	80	0.33	259	2145	27	1942	3281
4	80	0.33	259	2145	20	1439	2430
4	80	0.33	259	2145	18	1295	2187
6	120	0.33	388	3218	18	1942	3281

A high power 4 axle locomotive (1500 kW+) like the Vossloh DE18 becomes capable of medium freight and can compensate the lower train weight limit by higher speed compared to a 6-axle.

3.3 Conclusions

The performance envelope analysis confirms the Vossloh DE18 philosophy: a high power 4-axle locomotive (1800kW) offers an attractive versatility, covering tasks from heavy shunting to medium freight at reduced operating costs. The 1800 kW level also corresponds to the maximum power the 4 electric axles can reliably absorb (~400kW/axle).

4 Learning from previous modernization projects

4.1 Recent Known Diesel Re-Motorizations in Romania

Year	Project / Locomotive	Company	Original Engine	New Engine / System	Number Built	Success Grade	Result / Notes
2023	DEMA 3000 (060-DA rebuild)	Reloc Craiova	Sulzer 12LDA28	New complete motorization (Volvo diesels + AC)	1 (prototype)	Medium	Successful prototype, but no series production
2009–2015	LDH 1250 re-motorization	Remarul / Eneria	Original diesel	Caterpillar engines	Small batch	Good	Limited success; mainly hydraulic shunters
2016–2020	Various LDE / LDH studies	GEF Energy / ABC	Sulzer / EMD	ABC 6DZC / 8DZC proposals	0 (studies only)	—	Technical proposals only, no actual builds
2024–2026	LDH → Battery conversion	SCRL Brașov / Reloc	Diesel-hydraulic	Battery-electric (no diesel)	20 (planned)	In progress	PNRR-funded; not diesel re-motorization
2025–2026	LDE1250 / LDE2100	Any	Sulzer / EMD	None (only overhauls)	Very few	Low	No major re-motorization documented

4.2 Terra Nova

The **Terra Nova** locomotive is a diesel-hydraulic locomotive used mainly for heavy shunting operations and light line service. It is produced at Electroputere VFU-Reloc Craiova, Romania and it had its official launching in May 2014.

- It was diesel-hydraulic (two CAT C18 diesel engines + hydraulic transmissions).
- Only a very small number were built.
- It never became a commercial success.

4.3 LDH1250-Caterpillar re-motorization

- Engine replaced with a **Caterpillar 3508C** (V8, Stage IIIA/IIIB at the time, ≈ 1 000–1 100 kW).
- Cab, control system and some auxiliary components were modernized.
- A small batch was produced (probably 5–10 units, not a large series).
- Real examples: LDH 92 53 0841 024-8 (mentioned in 2010 at the Railway Days) and a few others that received AFER safety certificates in 2011.

Technically it was good: the Caterpillar engine is reliable, fuel consumption is better than the old Sulzer, and maintenance is simpler than the old Romanian engines. But it did not scale.

4.4 DEMA 3000

DEMA 3000 (Reloc Craiova / Grampet, 2023) is a **technical success but** Even Grampet (the owner of Reloc) chose the cheaper, available, faster imported **used Class 66** from UK.

- Chassis: 060-DA / LDE2100 (6-axle Co-Co)
- Original engine replaced with **4 × Volvo Penta diesels** (780 HP each → total ≈ 3 120 HP)

- Brand-new AC traction: **6 × 400 kW asynchronous motors** with individual inverters
- Max speed: 120 km/h
- Modern electronics, remote monitoring
- Status: successful prototype, EU certification in progress, one unit operating under GFR since 2024

It proved that a full Romanian rebuild with modern AC traction is possible and can deliver Class-66-level power.

4.5 CZ Loko – EffiShunter

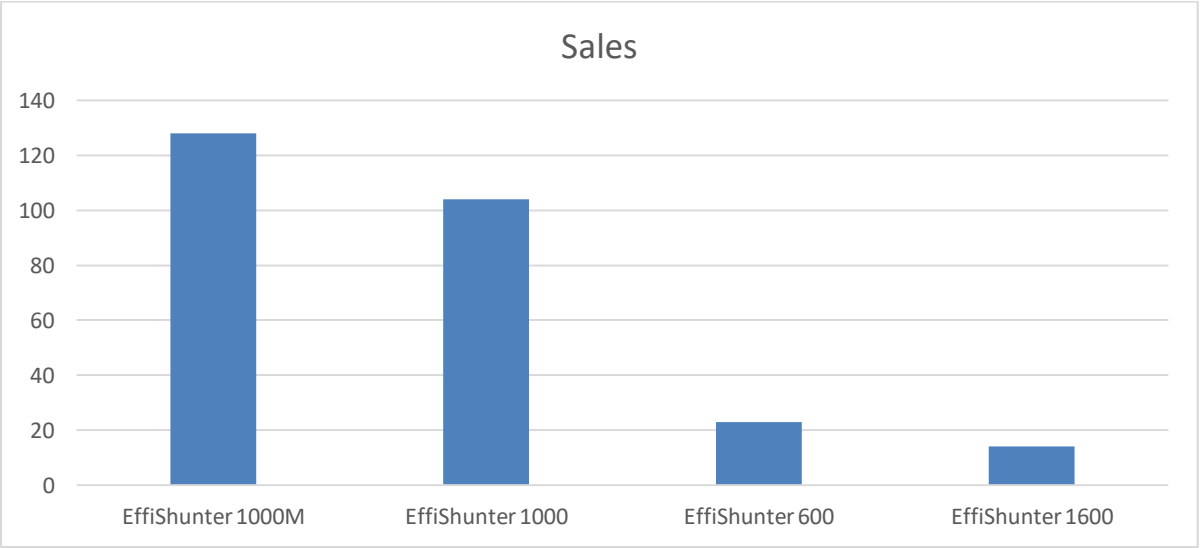
EffiShunter started as a modernization program too but it became a success story from Czeck Republic.

CZ Loko succeeded because:

- They started with massive repeat orders from state-owned ČD Cargo and ZSSK Cargo (modernizing old Class 742 to EffiShunter 1000M). That's hundreds of units locked in — protectionist, sure, but it gave them cash flow and proof-of-concept.
- Smart modernization, not full rebuilds — they keep the old frame/bogies, swap in CAT engines, AC traction, and modern controls. Cost stays low (~1.9–2.2 mil. €), reliability high.
- Export machine — once proven at home, they sold to Italy (DB Cargo Italia, Mercitalia), Slovakia, Hungary, even Scandinavia. Not huge numbers (maybe 40–50 real exports), but steady and competitive against Vossloh/Stadler.
- Timing + niche — Shunting/light line market is underserved. EffiShunter 1000 hits the sweet spot: 1 000 kW, ETCS-ready, Stage V emissions.

EffiShunter 1000: Von Sefjo - Eigenes Werk, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=35776676

EffiShunter 1000M is a modernization of Class 742. EffiShunter 1000 is new build. EffiShunter family has also other power variants, from 400kW to 1600kW, but the most successful are 1000kW variants.



The EffiShunter family proved the 1000kW engine power is in most demand.

4.6 Comparison

Locomotive	Producer	Units Sold	Powerplant	Diesel Engine output	Transmission	Hybrid	Certification
EffiShunter 1000	CZ Loko (Czech Republic)	**100+**	Caterpillar C32	**895 kW**	Electric (AC/AC)	No	TSI, Stage V, ETCS-ready
EffiShunter 1000M	CZ Loko (Czech Republic)	**120+**	Caterpillar CAT 3508C	**1000 kW**	Electric (AC/DC)	No	CZ/SK/HU/PL + ETCS (many units)
DEMA 3000	Reloc Craiova (Romania)	**1–2 (?)**	4 × Volvo Penta TAD 1643 VE-B	**4 × ~580 kW** (~2320 kW total)	Electric	No	Romanian + ERA (TSI)
TerraNova	Reloc Craiova (Romania)	**Few (2–3) (?)**	2 × Caterpillar C18	**2 × 470 kW** (940 kW total)	Hydraulic	No	Romanian
Vossloh DE18	Vossloh/CRRC (Germany)	**~215+**	MTU 12V 4000	**1800 kW**	Electric	No	Stage V, TSI, multi-country + ETCS
Vossloh DE18 Smart Hybrid	Vossloh/CRRC (Germany)	**50**	MTU 12V 4000 + traction battery	**1800 kW** (diesel)	Electric	Yes	Stage V, TSI, FR/BE/LU/DE + ETCS

4.7 Conclusions

Item	Observations	Lesson for LDX
Multi Engine	In theory offer better flexibility and fuel saving. But single engine locomotives sell better.	Choose a proven engine but with low total cost of ownership (e.g. MTU, CAT, MAN, ABC) with strong local service.
Small volume → lack of trust	Operators prefer solutions proven in large fleets.	You need prototype + rapid series production (20+ units in the first 2 years) so operators believe in the reliability.
Hydraulic transmission kept	Today everyone wants full AC traction (better control, regenerative braking).	LDX must have **electric traction**
No light hybrid / battery	Pure diesel only. No regenerative braking, no idle-stop, no zero-emission yard mode.	Without it you lose the green credentials and the 25–40 % fuel saving.
Certification	ETCS certification assure pan-European operation and thrust	ETCS or at least ETCS ready
Price	Vossloh: 4.5 M€ for 1800 kW CZ Loko: 2 M€ for 1000 kW	LDX must offer ~500kW/M€

5 Available Locomotive Engines

Manufacturer	Engine Model	Layout	Cyl	Capacity [L]	Power @ RPM	Stage	Approx Dry Weight [t]	Approx L × W × H (mm)
ABC Engines	6DZC-750	I6	6	102	950–1100 kW @ 750 rpm	IIIA+	11.5–13.0	4300 × 1700 × 2600
ABC Engines	6DZC-1000	I6	6	102	1200–1450 kW @ 1000 rpm	IIIA+	11.5–13.0	4300 × 1700 × 2600
ABC Engines	8DZC-1000	I8	8	136	1700–1900 kW @ 1000 rpm	IIIA+	15.0–17.0	5300 × 1750 × 2650
ABC Engines	10DZC	V10	10	170	2200–2600 kW @ 1000 rpm	IIIA+	18.0–21.0	4700 × 2200 × 2850
ABC Engines	12DZC	V12	12	204	2700–3200 kW @ 1000 rpm	IIIA+	22.0–26.0	5200 × 2350 × 2950
Caterpillar	C32	V12	12	32.1	895–1100 kW @ 1800 rpm	IIIA / V	3.2–3.8	2300 × 1600 × 1900
Caterpillar	3508E	V8	8	34.5	900–1300 kW @ 1600 rpm	IIIA / V	4.2–4.8	2700 × 1750 × 2050
Caterpillar	3512E	V12	12	51.8	1500–2250 kW @ 1600 rpm	IIIA / V	6.0–7.2	3100 × 1900 × 2200
Caterpillar	3516E	V16	16	69	2500–3385 kW @ 1600 rpm	IIIA / V	7.8–9.3	3600 × 2050 × 2300
MTU	12V1600	V12	12	26.8	700–1000+ kW @ 1800 rpm	IIIA / V	2.8–3.3	2200 × 1500 × 1800
MTU	12V4000	V12	12	57.2	1800–2400 kW @ 1800 rpm	IIIA / V	6.2–7.0	3300 × 1800 × 2200
MTU	16V4000	V16	16	76.3	2500–3400+ kW @ 1800 rpm	IIIA / V	8.5–9.8	3900 × 1900 × 2300
MAN Energy Solutions	D2862	V12	12	24.2	735–1100 kW @ 1800 rpm	IIIA / V	2.4–3.0	2100 × 1450 × 1750
MAN Energy Solutions	175D V12	V12	12	63	1500–2400 kW @ 1500 rpm	IIIA / V	7.0–8.5	3600 × 1900 × 2400
MAN Energy Solutions	175D V16	V16	16	84	2400–4000 kW @ 1500 rpm	IIIA / V	9.5–11.5	4300 × 2050 × 2500
Cummins	QSK38	V12	12	37.7	895–1100 kW @ 1800 rpm	IIIA / V	3.6–4.3	2500 × 1650 × 1950
Cummins	QSK60	V16	16	60.2	1600–2500 kW @ 1800 rpm	IIIA / V	6.8–8.0	3300 × 1900 × 2250
Cummins	QSK95	V16	16	95	2500–4000 kW @ 1800 rpm	V	9.0–11.0	4100 × 2050 × 2400
Sulzer	6LDA28	I6	6	111	1100–1325 kW @ 750 rpm	Legacy	12.0–14.0	4700 × 1650 × 2600
Sulzer	12LDA28	U12	12	222	2100–2650 kW @ 750 rpm	Legacy	20.0–24.0	5200 × 2400 × 3100
Progress Rail	EMD 12-710G3B	V12	12	139	~2238 kW @ 900 rpm	Legacy / IIIA var.	16.0–18.5	4600 × 2100 × 2800

ABC engines (6 DZC and 8 DZC) and CAT (3508E and 3512E) offer better scalability from 4 to 6 axle locomotives, enabling shared parts, common training and simplified logistics for a composed fleet. Although ABC has better Fuel Specific Consumption, fewer components (fewer cylinders) and higher TBO, the servicing is more difficult due to the size and weight of the components.

ABC is one of few low/medium revving big capacity diesel engines, supported mainly by the local need for naval propulsion for Belgian and European inland canals. They have a good coastal service network in EU, Africa and Asia.

https://www.abc-engines.com/en/service

Yet, we consider **Caterpillar family is a better solution** as the servicing is easier (smaller and lighter parts, much more compact design, lighter). This engine family is widely used in Europe and has good parts availability. The injection system is robust and more tolerant to fuel quality. Also, Caterpillar was already used in Romania for repowering projects, benefitting from local expertise.

6 Considerations

6.1 Profit Models

The operator makes profit by selling tonne-kilometers, as many as possible per day (or per month).

There are 2 scenarios:

1. Constrain is in the supply;
2. Constrain is in the demand;

1. Assuming constrain is supply not demand, profit comes from best cost for tonne-kilometers/hour.

Tonne-kilometers/h is energy/time, i.e. **POWER**.

In a supply constrained environment, the competitive advantage is given by **the best cost per kW**.

Example: after privatization and deregulations, rail operation in North America and Australia converged towards powerful locomotives (~4000 HP), working as Double or Triple Heading or Distributed Power, synchronized and controlled by a single crew.

2. Assuming constrain is demand not supply, profit comes from best cost for tonne-kilometers. Time is not a constraint anymore.

Tonne-kilometers are **ENERGY**.

In a demand constrained environment, the competitive advantage is given by **the best cost per kWh**.

> Side note: both theses are confirmed by the large share of electric locomotives on the market: production of power and energy is externalized and replaced by a (complex) power connection system and infrastructure.

6.2 Objectives

In Romania, the diesel electric locomotive will mostly operate on non electrified lines with slopes of 1-1.6% (see 2.3.2.), pulling 1200t trains. The market is rather demand constrained so the proxy for profitable operation is the cost/kWh. Also, significant pain points for the current aging fleet are:

- Reliability
- Spare parts

Objectives

Category	Objective	Importance
Affordability	Competitive Price	5
Uptime	High reliability	4
Availability	Spare Parts and Supply Chain	3
OpCost	Reduced operation cost	2
Versatility	Address the high unpredictability of future rail operations; Trans border operations;	2
Timing	Fast to homologate	2
Timing	Fast to build	2
Power	Adequate performace	2
Eco	Green credentials through light hybridization	1

7 The proposed LDX Family

The LDX is a modernization of the LDE1250 (4 axle) and LDE 2100 (6 axle locomotives), keeping the philosofy of high commonality of engine and drivetrain components.

Based on the market, operational, and technical insights presented above, the following modernization directions emerge as the most commercially viable.

7.1 Engines

A line of engines that is scalable to cover a wide range of powers on a common platform and with shared components, with high availability of parts is required.

Engine Family	Engine	Power
Caterpillar	C3508B	1000 HP
	C3512C	1500 HP

7.2 LDX models

7.2.1 LDX 1000 and LDX 1500

Model	Powerplant	Diesel Engine output	Transmission	Hybrid	Purpose
LDX 1000 4 axle	C3508B	**1000 HP**	Electric (DC)	No	Emulate the successful EffiShunter 1000M with an affordable, reliable operation solution: use a caterpillar genset and upgrade power electronics
LDX 1500 4 axle	C3512	**1500 HP**	Electric (AC)	100 kWh	Combine the successful EffiShunter 1000M and Vossloh DE18 Smart Hybrid into an competitive light hybrid that optimizes operation costs and more capability.

7.2.2 LDX 2000

Fuel consumption is reduced by the light hybridization that offers power boost during acceleration and regenerative braking on slopes

Model	Powerplant	Diesel Engine output	Transmission	Hybrid	Purpose
LDX 2000	C3512 HD	**2000 HP**	Electric (AC)	150 kWh	Combine the successful EffiShunter 1000M and Vossloh DE18 Smart Hybrid into an competitive light hybrid that optimizes operation costs and more capability.

7.2.3 LDX 3000

Model	Powerplant	Diesel Engine output	Transformer	Transmission	Hybrid	Purpose
LDX 3000	C3512	**1000 HP**	**3000 kW**	Electric (AC)	150 kWh	A cost effective alternative to the Dual Mode EURO9000 Locomotive: more affordable, versatile

8 LDX Powertrain + Control Module Matrix

Each variant is sharing parts and systems across the LDX family for easier logistics, trailing and maintenance. The shared modules are:

Code	Module	Description	LDX1500	LDX2000	LDX3000
C4	4 axle Bo-Bo Chassis	Original LDE1250	x		
C6	6 axle Co-Co Chassis	Original LDE2100		x	x
PM-D15	Prime mover 1500 HP	V12 diesel engine	x		2x
PM-D20	Prime mover 2000 HP	V12 diesel engine HD		x	
GEN-S	Main generator std	Diesel-coupled alternator/generator	x	x	2x
GEN-H	Main generator heavy	Higher output alternator		x	
DCB-1	DC link bus std	Main HVDC bus + protection	x		
DCB-2	DC link bus heavy	Higher current DC bus		x	x

Code	Module	Description	LDX1500	LDX2000	LDX3000
INV-T	Traction inverter module	One module drives 1 motors	4x	6x	6x
MTR-500	Traction motor	AC traction motor 500 kW class	4x	6x	6x
AUX-75	Aux converter std	HVAC, compressors, controls	X		
AUX-120	Aux converter heavy	Larger hotel/aux loads		X	X
BAT-100	Battery pack	100 kWh LFP pack	X		
BAT-150	Battery pack	150 kWh LFP pack		X	X
BMS	Battery management	Monitoring, balancing, thermal	X	X	X
DC/DC	Battery interface	Battery to DC bus bidirectional	X	X	X
BRK-ED	Dynamic brake chopper	Dissipative resistor bank	X	X	X
REGEN	Regen control	Battery / line energy recovery logic	Opt	Opt	Std
HV-TR	Main transformer	OCS AC to traction bus			X
HV-LC	Line converter	Rectifier / active front end			X
PAN	Pantograph	Roof collector assembly			X
VCU	Vehicle control unit	Whole-loco supervisory logic	X	X	X
TCU	Traction control unit	Slip-slide / torque control	X	X	X
EMS	Energy management system	Diesel/battery/grid dispatch logic	X	X	X
ECG	Engine control gateway	Interface to diesel ECU	X	X	X
HMI	Driver display/control	Cab screens + diagnostics	X	X	X
RDM	Remote diagnostics	Telemetry/fault reporting	Opt	Opt	Opt
ETCS	Train protection	ETCS integration	Opt	Opt	Std

9 LDX vs. Competition

Feature	LDX1500	EffiShunter 1000M	Used Class 66	Vossloh DE18
Price (Romania)	2.2–2.6 M €	**~2.0 M €**	1.4–2.2 M €	4.0–4.5 M €
Power (diesel)	1100 kW	895 kW	2460 kW	1800 kW
Hybrid system	Yes (light hybrid)	No	No	Yes (SmartHybrid only)
Fuel savings	15–25%	0%	0%	15–20%
Traction type	AC	DC	DC	AC
Adhesion / low-speed control	High	Medium	Medium	High
Gradient performance (1.0–1.6%)	Excellent	Weak	Good	Excellent
Train weight capability	Up to 1200 t	600–900 t	1500–2000 t	1200–1500 t
Maintenance cost	Medium	Medium	High	Medium
Engine lineage	ABC 6DZC (modern Sulzer)	CAT C32	EMD 710	MTU 4000
Parts availability (RO)	Very high	Medium	Medium–low	Medium
ETCS	ETCS-ready	No	No	Optional
Noise / emissions	Stage IIIA → V-ready	Stage IIIA	Stage II	Stage V
Primary role	Shunting + light/medium freight	Shunting	Heavy freight	Shunting + freight
Rebuild or new-build	Rebuild (low CAPEX)	New-build	Used import	New-build
Target operator	Romanian private freight	Industrial + CZ/SK	GFR / heavy freight	Western EU

10 LDX Roadmap

10.1 Phase 1: setup

1. Find potential operator interested in the program LDX 1900, at least 20 units
2. Make consortium for LDX 1900 collaborative build

10.2 Phase 2: LDX 1000/1500

3. Build prototype
4. Certification in HU (apparently faster) – mutual recognition in RO
5. Deliver initial batch. Fix early teething problems
6. Deliver full batch (20+). Gather data. Solve Findings. Prove reliability.

10.3 Phase 3: Scale to LDX 2000

7. Scale up to 6 axles and build prototype
8. Certification in HU (apparently faster) – mutual recognition in RO
9. Deliver initial batch. Fix early teething problems
10. Deliver full batch (20+). Gather data. Solve Findings. Prove reliability.
11. Export to Africa/Mauritania

10.4 Phase 4: Scale to LDX 3000

12. Combine catenary with LDX1000 powertrain
13. Certification in HU (apparently faster) – mutual recognition in RO
14. Deliver initial batch. Fix early teething problems
15. Deliver full batch (20+). Gather data. Solve Findings. Prove reliability.
16. Export to WE