

# BEV to REEV: Enhancing EV Platforms with Range Extenders

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Despite advancements in electrification, perceived flexibility and autonomy of BEVs fall short of customer expectations, necessitating enhanced appeal without compromising their core essence.



### **BEV Market: Status Quo**





Architecture voltage in V

\* Based on evaluation of publicly available data for approx. 800 vehicles sold in Europe from 2020 onwards.

#### **Overall huge efforts towards electrification**

- 400+ BEV models available to order in Germany today
- Range with state-of-the-art technology sufficient for large majority of use cases
- Continuously improving charging speeds eliminating constraints
- ... but have these paid off?

Perceived flexibility and autonomy still not fully on par with customer expectations.

Boost electric vehicles' subjective appeal while preserving their essence.

## How to Hybrid in 2025? And Why?

#### ICEV-based

Local emission-free driving, better acceleration, lower  $CO_2$ 



Hybrid

Hybrid development no longer confined to ICE platforms: BEVs emerging as a viable alternative, yet with distinct objectives

#### **BEV-based**

Boost appeal while maintaining core identity



## REEVs in the Spotlight What Is the Twist this Time?



Selected popular on-sale and upcoming hybrids



#### **ICEV-based**

Low battery capacity, low e-power, low e-range, parallel(-series)

#### **BEV-based**

High(er) battery capacity, high e-power, high e-range, series

A "modern" REEV is a BEV-based series hybrid<sup>\*</sup>. Use of ICE only in exceptions.

- Boost the appeal, maintain the identity: BEV with "unlimited" range
- Customer expectations crucial for concept success (correlating with market, segment, price)
- Costs & time to market vs. optimized components?

 $^{\ast}\,$  Series-parallel hybrids with high electric range are sometimes classified as REEVs well.



**REEVs in the spotlight: Boost the** appeal, maintain the BEV identity.

# **BEV to REEV: Navigating the Transition**



Minimum  $CO_2$  and pollutant emission

> Scaling existing platforms powers component rightsizing and compatibility, slashes costs, and turbocharges time to market.

### Range: RE vs. EV



WLTC electric range of REEVs starting from the battery capacities of their BEV counterparts Electric range decisive for charging behavior of users

Battery capacity of  $\approx$  40 kWh sufficient even at cold conditions for > 98 % of users to regularly charge<sup>\*</sup>

Reduction of capacity impacting cost, weight, volume, energy consumption and battery system design

Rightsizing battery capacity for minimum ICE use and leveraging additional component cost.

#### How to right-size?

\*Wang, R., "Aurobay - Powering a hybrid future," 33. Aachen Colloquium Sustainable Mobility, 2024.

### **REEVing the High-Voltage Battery**

#### **Pack parameters**

Scaling with battery capacity: Cycle count, weight, volume  $\rightarrow$  accelerated ageing (mileage)

**Required to be maintained:** Voltage level, power output  $\rightarrow$  high-power cells?

**Depending on the platform:** Cell count, module count, cell size

**Impact system and vehicle:** Weight distribution, thermals, structural stiffness, regulatory compliance

#### Integration level vs. capacity scalability

**Less modules:** Straightforward, but low flexibility at system level

Less cells: More flexibility, but design changes

**Change chemistry:** E.g., low-cost LFP, but compromise weight and volume

**Tailored:** Tailored to application with dedicated format, chemistry

Scalability paving the path for low costs and accelerated time to market, approach tailored to platform specifics.

# Packaging: Optimized BEV vs. ICE for ICEVs



- REx-packaging primarily linked to BEV degree of optimization: Wheelbase, shape, aerodynamics ...
- No clear correlation between vehicle size and frunk availability and size\*

A "good" BEV is a more challenging basis for a REEV, absolute vehicle size of low importance

Packaging task strongly individual → Scalability

\* Based on evaluation of publicly available data for approx. 800 vehicles sold in Europe from 2020 onwards.

## Scaling the ICE to a REx



Scaling existing ICE platforms can yield technically competitive and cost-efficient solutions.

#### A general assessment based on IAV's ICE and BEV CAD databases (focus C-SUV and E-Sedan)

#### I4 mounted "as usual"

Feasible in low-optimized or BEVs with large (and deep) frunks.

#### "Lying" I4 (horizontal)

Flat and quiet(er), modifications to oil and coolant systems, production line?

#### H4

Flat and quiet, but make or buy?

#### **REEV-dedicated**

I2, H2, V2...? Have been there before. Or rather something new? We can do.



A REEV needs more than an ICE ... take over eAxle and CC EAT, underfloor exhaust (side pipes for some markets), integrate generator (omit flywheel?), scale and integrate fuel tank, leverage synergies

### **NVH: Custom Sound Design with a "Purring Cat"**

#### **1000 ccm REx operating point distribution** in RDE highway cycle



4 cyl. inline ICE

Vertical – base mounting position
 Vertical – base mounting position – stiff
 Horizontal – base mounting position – stiff
 Horizontal – tase mounting mounting position

- Vertical I4: Longitudinal and especially vertical vibrations
- Horizontal I4: Lower forces transmitted to the structure
- Torque-roll-axis mounting & REx: No static moments and minimized forces from harmonic moments
- Active mounts: Mitigate vibrations from harmonic moments,
  ≈ 2 dB(A)
- H4: Lowest vibration levels (but not by far)

Structure-borne noise highly predominant, airborne noiserelated measures not economically viable.

Platform scalability enabling significant NVH improvements, sound levels at driver's ear comparable with pure BEV.

# **REx: Layout, Performance, Emissions**

Maintain identity: No compromises in terms of vehicle performance



- Same top speed with ICE power only,
  > 70 kW REx peak (electric) output
- Driving dynamics always by battery system (operation strategy!)

# Rightsize the REx: Performance at minimum cost & CO2 penalty



- ICE layout and tech. package for legislation and customer use cases
- Real-world operation ideally
  long-distance highway driving

#### Despite long REEV electric range the REx will have CO<sub>2</sub>-impact (fuel?)



- Continuous reduction of fleet CO<sub>2</sub>- limits to below 50 g/km
- Customer expectations crucial for concept success (vehicle sales)

C-segment SUV REEV 40 kWh 1.2L NA PFI 1.0L TC DI

### **Costs: Active Material vs. Additional Components**



Cost-saving potential influenced by energy storage market dynamics, but REEVs can be offered at a competitive price.

#### **Battery system savings**

- Lowering battery capacity enabling leveraging REx costs
- Chemistry switch providing additional cost reduction boost

#### **REx (+periphery) cost**

- REx cost efficiency through existing technologies and production lines
- NA PFI ICE requires larger displacement, offsetting space-saving and cost advantages
- Boxer more expensive, REx for pure BEV manufacturers as a purchased low-cost component

### **BEV to REEV: High-Level Summary**

ICE layout	4-cyl. inline vertical	4-cyl. inline horizontal	4-cyl. boxer	REx- dedicated
Packaging		+	+ +	++
Costs	++	+	+ + / -	-
NVH	-	+/++	+ +	+
Scalability	++	+	-	+
Extra range	-	- / o	0	+
Time to market	+ +	+	+ + / -	

#### **REx concept**

- I4 horizontally mounted as REx a good compromise
- 1.2L 1.5L NA providing good balance, technology pack ultimately depending on platform scalability (benefit – cost)
- REx-dedicated technically superior, but higher costs and longer time to market

Economically viable REEV concept through platform scaling, designed around customer expectations: BEVlike driving and ownership experience.

### **SDV-Ready: Powertrain Abstraction Layer**



### Prospectives and Outlook Here to Stay?



#### SD(REE)V

- SDV-ready with REx abstraction layer
- Cloud-based predictive operation strategies for minimized energy consumption and maximized lifetime
- Implementation of additional, REEV-specific features, e.g., geofencing



#### **REEV Gen. 2**

• REEV: Just a trend?

The market will decide. But also legislation driven.

- "Modern" REEV Gen. 2?
  - Dedicated REx, or ICE enabler for one-platform approach?

The BEV to REEV transition allows IAV to enhance the perceived flexibility and autonomy of electric vehicles, addressing customer expectations.

The scalable platform concept drives component compatibility, lowers costs and accelerates time to market.

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## Many thanks to all contributing colleagues!

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